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# Remedy for a Failure

Reading "The Working of Joint Consultation"* we were conscious of having seen the publication earlier in some other form, probably as a series of preprints. Now, having this collection of five papers, we cannot help but draw the conclusion that, except for a few well known and really outstanding cases, joint consultation has been an abysmal failure. It is clear from this pamphlet that the important rôle played by the foreman has only too often been neglected—indeed his grade is often without representation on the committees. After the committees have been established some time, they find themselves dealing with petty matters affecting the workman-representative personally or his nearby mates, that is, "they were most concerned about and influenced by the relationships in which they, themselves, were directly involved." These are the very matters which could be best dealt with on the spot, quite informally, by the foreman. Perhaps the most outstanding comment in this pamphlet is that where the personal relationships between the foreman and the directors and the leading managers were truly cordial, then the "employees were more favourably disposed towards the firm and higher management."

It is doubtful if sufficient managers realize the profound effect the promotion of a workman to foreman has on his social life and outlook. It is at this point that he needs help, encouragement and sympathy from the higher management. It is not merely at this time but throughout his career that he should be made to feel an important part of management—as indeed he is. It is true to state that some of the essentials of managerial skill—a prerequisite of successful foremanship—are innate but others can be acquired. It is thus essential that every opportunity be given for the acquisition by the foreman of additional skills, to help him in his difficult task. Attendance at foremen's conferences and the taking of T.W.I. courses are extremely helpful, but the essential is to make a foreman realize that he is one of the key men of the firm.

It would appear that the best approach to joint consultation is to start a system through which the whole of the management from the managing director down to the most-recently-appointed foreman should be welded into one homogeneous team, It should be borne in mind that the neophyte foreman should be welded into one homogeneous team. grievances of the workmen better than the men themselves, for they, according to this pamphlet, often find difficulty in expressing themselves. In recent years, the trade unions have extended their activities far beyond the boundaries of wages and hours, and they now embrace within their activities, collaboration with the employers on every phase of working conditions and hygiene. These efforts certainly tend to make joint consultation merely academic. Thus, general questions can well be left to the normal negotiating channels and particular ones to the good offices of the foreman.

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**MR. P. H. WILSON, O.B.E. M.I.Mech.E**

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# *Leaders of the Industry*

## P. H. WILSON, O.B.E., M.I.Mech.E.

FOR more than 40 years, Mr. Percy Hutchinson Wilson has been an outstanding personality in the foundry industry. He served his apprenticeship partly with the Whessoe Foundry Company, Darlington, and partly with Markham & Company, Limited, Chesterfield. After spending some time at the Widnes Foundry Company's works as castings inspector for the Liverpool Corporation Waterworks, he was employed for seven years by James Oakes & Company, Alfreton Ironworks, as castings inspector and later as works superintendent. In the year 1911, he was appointed works manager and engineer by the Staveley Coal & Iron Company, Limited, near Chesterfield. After 8-yrs'. service he relinquished this position to become foundry general manager with the Stanton Ironworks Company, Limited, with which firm he has since remained. In June, 1940, Mr. Wilson became assistant managing director (technical), and in December, 1953, was appointed deputy managing director, which position he still holds.

In 1905, Mr. Wilson joined the Institution of Mechanical Engineers as a graduate, and has been a member of the Institute of British Foundrymen since 1918. In 1942, he was awarded the E. J. Fox Gold Medal and was president of the Institute in 1947-48. For a number of years, Mr. Wilson has been intimately connected with the work of the British Cast Iron Research Association, and held the office of president for the period 1948-50.

During the first world war he was instrumental in conjunction with the Ministry of Munitions in producing specifications for high-duty irons. During the second world war he was mainly responsible for the design, construction and operation of one of the largest mechanized steel foundries for the mass production of steel bombs. For this service he was awarded the O.B.E. in 1943. Mr. Wilson is particularly well-known for his successful pioneer work in the development of the principle of centrifugal casting and its application to the manufacture of cast-iron pipes. On this subject he is a recognized authority, and has written several valuable papers. An indication of his inventive mind is shown by the large number of Patents in his name.

Since 1908, when Mr. Wilson was a lecturer in engineering subjects at evening classes, he has been keenly interested in the training of youth for the foundry industry, and he was responsible for the installation of a fully-equipped training centre at Stanton, which was opened in June, 1947. In 1951, Mr. Wilson was appointed by the Minister of Education to be chairman of the Governors of the National Foundry College and still holds this important office. In 1950, he was admitted as a Serving Brother to the order of St. John of Jerusalem. Mr. Wilson is also a Liveryman of the Worshipful Company of Founders, a freeman of the City of London and a member of the Fellowship Committee of the Company. Mr. Wilson's principal hobbies when time permits are golf, bowls and gardening.

## I.V.E. Summer School

The second Summer School organized by the Institute of Vitreous Enamellers was held at Ashorne Hill, near Leamington Spa, Warwickshire, from Friday, June 19, to Sunday, June 21, and the programme, which included the following papers, was enthusiastically received:—"Importance of Adequate Process Control in the Vitreous-enamelling Industry," by S. Hallsworth; "Process Control of Metal Preparation Processes: (*a*) Cast Iron," by A. K. Williams, and (*b*) "Sheet Iron," by H. W. Clewes; "Process Control in the Millroom," by H. Symonds; "Enamel Application Processes," by T. J. McArthur, and, finally, "Furnace Control and Fusing," by S. E. A. Ryder. Films were also shown. There were opportunities given for the discussion of delegates' problems and experiences. Although the basic cost of the School was again borne by the Institute and the only charge to individuals was for accommodation and meals, it is regrettable that the School was not very well attended.

## Foundrymen Anglers

Twenty-eight members of the Allied Ironfounders' Social and Sports Club (Angling Section) travelled by special bus to fish the fifth competition for the Hill Cup, permission having been received to fish a two-mile stretch of private water on the River Tummel at Ballinluig. The prize-winner was J. Bennett, of Falkirk Iron Company, Limited, with five trout weighing 3.7 lb., the heaviest being 1 lb. 14 oz. A special prize was donated by J. Don for the heaviest fish caught by a competitor not in the official prize-list. It was won by G. Craig, of Callendar Abbots, with a grilse weighing 2 lb. The Hill Cup aggregate, after five competitions, is now:—J. Bennett, 8 lb. 15 oz.; F. Charleston (Abbots), 6 lb. 12 oz.; M. Reif (Falkirk Iron), 3 lb. 3 oz. Arrangements were completed during the journey to fish the sixth and final competition for the Hill Cup on Loch Rannoch and Tummel later this month.

## Forty Years Ago

In the issue for August, 1913, of the FOUNDRY TRADE JOURNAL, the leading article was devoted to a plea for better shops, having proper lighting and ventilation and furnished with up-to-date plant. If "sanitary convenience" is meant to include changing and bathing facilities, then this article would stand reprinting to-day. Some of the remarks were no doubt prompted by a Factory Department report on lighting in foundries. Arc lamps were currently used, but clustered inverted gas mantles were favourably commented upon. Fish-tail burners gave bad results. Yet electricity was not then universally available at an economic price.

There is a paper on the influence of silicon on the corrosion resistance of cast iron, for silicon contents ranging from 1.24 to 2.28 per cent. In the conclusions, it is put forward that higher percentages of silicon might decrease corrosion. The *Association Technique de Fonderie* held a convention and exhibition and four British papers were presented, two of the authors being Rosenhain and Hatfield. The London foundry of Mr. J. Oswald was converted into a limited company as J. Oswald & Sons, Limited.

## Latest Foundry Statistics

According to the Ministry of Supply the production of aluminium-alloy castings during May was 1,657 tons of sand castings; 2,690 tons of gravity- and 753 tons of pressure-die-castings. The corresponding figures for the first five months of the year were 8,900, 13,399 and 3,957 tons.

From figures of the British Bureau of Non-Ferrous Metals Statistics, the output of copper-base castings during June was 5,119 tons and for the first half year 24,636 tons as against 35,382 tons during the corresponding period of 1952.

*As a souvenir of his work in connection with the Blackpool Conference of the Institute of British Foundrymen, the organizing committee presented Mr. T. Makemson, M.B.E., with a fountain-pen set. To Mr. G. Lambert a suitcase was given. In the picture, left to right, are Mr. Harper, Lancashire branch president; Mr. Lambert, Mr. Longden (president of the Institute), Mr. Cook, Mr. Yeoman (chairman, conference committee), Mr. Makemson and Mr. Jackson.*

# Effect of Heat on Clays and its Bearing on the "Life" of Clay Bonds*

*By S. Davidson, B.Sc., and J. White, D.Sc.*

*All clays when in their normal "air-dried" condition lose water on heating. This water is of two kinds* (a) *adsorbed water, and* (b) *chemically-combined moisture which is formed as a result of the loss of hydroxyl groups present in the clay mineral as an essential part of its structure. The loss of adsorbed moisture, which takes place largely at* 110 *deg. C. and to a less extent at temperatures slightly above this, is generally completely reversible,* i.e., *in a humid atmosphere the moisture lost will be picked up again and the clay will be found to have changed little if at all in its properties. The loss of chemically-combined moisture generally begins at temperatures over* 400 *deg. C. and is essentially complete if sufficient time is allowed at temperatures of the order of* 550 *to* 700 *deg. C., depending on the nature of the clay. This loss is accompanied by a breakdown of the clay structure and is, therefore, irreversible since the clay cannot, under normal conditions at least, be reformed. It is accompanied by almost complete loss of the ability to become plastic with water. The effect of heat on all clays is thus ultimately to destroy their bonding properties. This will always happen to the clay in a mould in the immediate vicinity of the mould/metal interface, where the temperature is high enough to decompose the clay completely and almost instantaneously. There exists in the mould, however, a much deeper zone where the maximum temperatures reached lie between say* 400 *and* 700 *deg. C. in which the time/temperature conditions are such that clays with different dehydration characteristics may be expected to show appreciable differences in the degree of breakdown they will undergo during a given cycle of use. This might reasonably be expected to be reflected in differences in the "life" of the clay bond in service. The object of the present investigation was to determine whether such a relationship between breakdown characteristics and "life" did in fact exist, and to ascertain to what extent such differences in behaviour could be correlated with changes in the chemical and physical properties of the clays during heating.*

## PART I.

### (1) Nature of Clays

The use of X-ray and petrographic methods has established that clays are composed of "clay minerals" of definite structure, together with various impurities such as quartz, mica, felspar, calcite, etc., which generally tend to reduce the plastic properties at low temperatures and at high temperatures contribute to the fluxing reactions, thus affecting the ultimate fusion characteristics. In the intermediate temperature zone in which decomposition of the clay occurs, they have probably only a minor effect, though the decomposition of materials such as calcite may be expected to have an effect on the pH value and consequently the plastic properties of the clays after heating.

Structurally, the clay minerals belong to the "layer-lattice" group of minerals which consist of sheets of oxygen ions laid on top of each other and having the metal ions (cations) in the interstices between them. Two types of oxygen sheet occur, one with a close-packed and the other having a hexagonal type of packing. These have been named the X and Y sheets respectively.[1]

In kaolinite—the principal clay mineral in china clays, ball clays and fireclays—three oxygen sheets are laid over each other in a sequence X–X–Y to form a unit layer or "pad." The $Al^{3+}$ ions occur in octahedral spaces (each bounded by six oxygen ions) between the X sheets, there being as many octahedral spaces as there are oxygen ions in each sheet. Two-thirds of the available spaces are occupied by the $Al^{3+}$ ions, the remainder being unoccupied. The $Si^{4+}$ ions occur in tetrahedral spaces (each bounded by four $O^{2-}$ ions) between the X and Y sheets, the number of such spaces being equal to two-thirds of the number of $O^{2-}$ ions in each sheet. All these tetrahedral spaces are occupied. In addition, all the oxygen ions of the outer X sheet and one-third of the oxygen ions of the inner X sheet have $H^+$ ions associated with them to form $OH^-$ groups. The various ions are thus in the proportions $(OH)_8 : Al_2 : O_5H : Si_2 : O_5$, corresponding to $Al_2Si_2O_5(OH)_4$ or $Al_2O_3.2SiO_2.2H_2O$, and the structure is electrically neutral since the sums of the charges on the positive and negative ions are equal. Actually, the unit cell (the unit of pattern in the structure) contains the equivalents of two molecular weights of $Al_2O_3.2SiO_2.2H_2O$, so that it can be represented by the structural formula

$$Al_4^{VI}\ Si_4^{IV}\ O_{10}\ (OH)_8$$

where the Roman numerals indicate the co-ordination numbers of the metal ions (*i.e.*, the number of nearest-neighbour $O^{2-}$ ions surrounding them) and hence their positions in the structure.

Crystals of kaolinite are formed by stacking the layers or pads on top of each other, the stacking taking place in such a way that the $O^{2-}$ ions and $OH^-$ ions of X and Y sheets of adjacent layers approach each other. By stacking the layers in slightly different ways, while still satisfying this condition, crystals of different symmetry are produced, *e.g.*, the kaolinite-group minerals, kaolinite, dickite, and nacrite differ from each other only in this respect.[2] In each of these, the manner of packing is regular but differs from that in the other two. There also

* Paper presented to the fiftieth annual meeting of the Institute of British Foundrymen at Blackpool.

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exist, however, clay minerals of the kaolinite type in which the sequence in which the layers are stacked is irregular. An extreme example of this is found in halloysite.[3] In addition, halloysite differs from the above three minerals in that it can accommodate water molecules between the layers giving a composition, in the fully-hydrated form, corresponding to $Al_2O_3.2SiO_2.4H_2O$. Half of this water is, however, readily driven off at low temperatures, when it reverts to the composition $Al_2O_3.2SiO_2.2H_2O$. Provided this dehydration is carried out at a low enough temperature, preferably below 100 deg. C., this moisture loss is reversible. In many fireclays, and possibly also in some ball clays, the kaolinite has a similarly disordered structure, though the degree of disorder or randomness is less than in halloysite.[4] The kaolinite occurring in such clays is thus intermediate in properties between true kaolinite and halloysite. A point of practical significance is that these disordered structures lose their chemically-combined water at rather lower temperatures than does fully-ordered kaolinite. Thus the temperature of the dehydration peak on the differential thermal analysis curves of such clays is generally found to be some 10 to 15 deg. C. lower than that of kaolinite.

**Bentonite Clays**

In montmorillonite, the essential clay mineral of bentonites, the unit layer is built up from four oxygen sheets in the sequence Y–X–X–Y. In the "ideal" structure the $Al^{3+}$ ions again occupy two-thirds of the available octahedral spaces between the pair of X sheets, while the $Si^{4+}$ ions occupy all the tetrahedral spaces between the X and Y sheets. In addition, one-third of the oxygen ions in the X sheets have $H^+$ ions attached to them, the structure again being electrically neutral. The ions are thus in the proportions $O_2 : Si_2 : O_3H : Al_2 : O_3H : Si_2 : O_2$, corresponding to $Al_2O_3.4SiO_2.H_2O$. As there are again two molecular weights in the unit cell its structure can be written :—

$$Al_4^{VI}\ Si_8^{IV}\ O_{20}\ (OH)_4$$

This structure corresponds to the mineral pyrophyllite Actual montmorillonites, micas, etc., can be considered as being derived from this structure by partial substitution of $Si^{4+}$ by $Al^{3+}$ in the tetrahedra. positions and of $Al^{3+}$ by $Mg^{2+}$ and $Fe^{2+}$ in the octahedral positions. Thus in muscovite (white mica) one quarter of the $Si^{4+}$ ions is replaced by $Al^{3+}$ ions,[5] giving the composition of the layer per unit cell as :—

$$Al_4^{VI}\ (Si_6\ Al_2)^{IV}\ O_{20}\ (OH)_4$$

There are then two excess negative charges on the layers per unit cell. This charge is neutralized by the presence of $K^+$ ions in the spaces between the layers, *i.e.*, there are two inter-layer $K^+$ ions per unit cell or one to every 12 oxygen atoms (including OH oxygens). This gives the final structure of the unit cell as $K_2^{XII}\ Al_4^{VI}\ (Si_6\ Al_2)^{IV}\ O_{20}\ (OH)_4$. The co-ordination number of the $K^+$ ions is written as 12 since it fits into a space formed by two hexagonal rings of oxygen ions belonging to the Y sheets of the two adjacent layers.

In montmorillonites, the extent of the lattice replacement is considerably less than in mica, the excess negative charge being approximately 0.67 elementary charges instead of 2 per unit cell.[6] These are neutralized by the presence of cations such as $Na^+$, $Ca^{2+}$ etc., in the inter-layer spaces. The Si : Al ratio can vary over a considerable range depending on the type of replacement occurring; *e.g.*, when replacement is confined to the substitution of $Mg^{2+}$ for $Al^{3+}$ in the octahedral positions the resulting structure will be :—

$$(Al_{3.33}\ Mg_{0.67})^{VI}\ Si_8^{IV}\ O_{20}\ (OH)_4$$
$$\vdots$$
$$M^+_{0.67}$$

where $M^+$ represents a univalent, inter-layer cation. The Si : Al ratio is then approximately 5 : 2. If, on the other hand, it is confined to substitution of $Al^{3+}$ for $Si^{4+}$ in the tetrahedral positions the structure will be :—

$$Al_4^{VI}\ (Si_{7.33}\ Al_{0.67})^{IV}\ O_{20}\ (OH)_4$$
$$\vdots$$
$$M^+_{0.67}$$

and the Si : Al ratio is approximately 3 : 2. Both higher and lower values of the Si : Al ratio than these can occur, however, because in actual montmorillonites, the number of cations in the octahedral positions has been found to vary over the range 4.00 to 4.44. When the number is greater than 4.00 this necessitates a higher degree of replacement in either the octahedral or tetrahedral positions to maintain the excess negative charge at what appears to be the preferred value of 0.67 units per unit cell. In still another series in which the cations in the octahedral positions are predominantly $Mg^{2+}$, the number varies from 5.76 to 6.00. The name montmorillonoid has been proposed by MacEwan[6] to cover all these modifications, montmorillonoids falling within the former range being described as di-octahedral (indicating that roughly two out of three octahedral positions are filled), and those falling in the second range as tri-octahedral montmorillonoids. The name montmorillonite was originally proposed by Ross and Hendricks[7] for a di-octahedral montmorillonoid approximating to the first of the above formulae, *i.e.*, having a Si : Al ratio of about 5 : 2. MacEwan[6] proposes to retain the definition and further proposes that the name beidellite should be retained for material approximating to the second formula. He considers that a continuous series, involving progressive replacement of $Al^{3+}$ by $Fe^{2+}$, exists between beidellite and nontronite in which all the $Al^{3+}$ has been so replaced. Another proposal is that montmorillonites should be classified by the ratio of $SiO_2 : Al_2O_3$ (or 2Si : Al).[8] Thus, the first of the above formulae would correspond to montmorillonite-5, the second to montmorillonite-3, and so on.

**Swelling Property**

A characteristic feature of montmorillonites is that their inter-layer cations have the power of drawing moisture between the layers causing the crystals to swell in a direction perpendicular to the layers. Thus, whereas the dried material has a characteristic lattice spacing of about 9.6Å. (1 Ångström unit = $10^{-8}$ cm.), in the presence of moisture (including the

moisture in the atmosphere) the value can vary from about 12 to 20Å. depending on the humidity. Further, if the clay is treated with water containing other cations in solution it is found that these can replace the original inter-layer cations. This constitutes what is known as base exchange or cation exchange. A charge of 0.67 elementary charges per unit cell corresponds to a base exchange capacity of approximately 83 milli-equivalents of exchangeable cations per 100 gm. of dried clay.

### Secondary or Hydrous Clay Micas

Another group of clay minerals based on the Y-X-X-Y sequence of oxygen sheets is the secondary micas or hydrous clay micas so called because of their structural similarity to the micas, though their particle size falls within the clay range. They occur in the fine fractions of many clays and in certain shales, and resemble the micas in having an appreciable content of potash. This, however, is lower than in the true micas while their content of combined moisture is higher. The name illite was first proposed by Grim, Bray and Bradley[9] in 1937 as a general term for minerals of this group. The position has since been complicated, however, by the discovery that many clay minerals of this type contain layers of other types, *e.g.*, montmorillonite, interstratified either in a regular sequence or in a random manner with mica-type layers.[8] The name illite, therefore, it is now proposed,[10] should be restricted to materials containing only mica-type layers. The latter may be either di-octahedral, when they can be considered to be derived from muscovite (see earlier), or tri-octahedral, when they can be considered to be derived from phlogopite (a mica derived from muscovite by replacing the four $Al^{3+}$ cations in the octahedral positions by six $Mg^{2+}$ cations, or from biotite, in which the six octahedral positions are occupied by a mixture of $Mg^{2+}$ and $Fe^{2+}$ cations). Characteristically, the illites are non-expanding minerals with a basal spacing of approximately 10Å., and have a base exchange capacity of the order of 40 m.-e. per 100 gm. The mixed-layer structures, on the other hand, due to the presence of hydratable layers (*i.e.* layers which can hold inter-layer moisture films) have basal spacings of 10Å. "mixed" with basal spacings of higher values. On heating, the latter contract so that a single basal spacing is observed. Hydrobiotite, a mineral of this type, which has been identified in certain clays, has a mixed structure of mica-type and vermiculite layers, this latter being a tri-octahedral mineral related to biotite and phlogopite but containing $Mg^{2+}$ in the inter-layer position. Mixed-layer minerals have generally base exchange capacities lying in the same range as the illites.

While the base exchange capacity of montmorillonites and illites is mainly attributable to the cations held between the layers, it appears likely that in all clay minerals a small proportion of their base exchange capacity is attributable to cations associated with the external surfaces of the particles. Thus, kaolin, in which, as has been seen, the layers are apparently electrically neutral and which has, therefore, no inter-layer cations, is generally found to have a cation exchange capacity of the order of 8 to 10 m.-e. per 100 gm. or less. (It is possible that the true value is less than this—possibly of the order of 1 to 2 m.-e. per 100 gm.—and that the higher values are due to the presence of montmorillonite illite, etc., as impurities.) This is generally considered to be associated mainly with the surfaces formed by the edges of the layers where broken bonds, *i.e.*, unsatisfied valencies, capable of attracting additional cations can be expected to occur.

(2) Condition of Adsorbed Moisture in Clays

When dried clay is placed in a humid atmosphere it adsorbs moisture until a state of equilibrium is reached, *i.e.*, until its vapour pressure equals that of the atmosphere. In the case of non-expanding clay minerals, this moisture is adsorbed on the outer surfaces of the particles and even at relatively high humidities is generally of the order of only a few per cent. of the weight of the dry clay. In the case of expanding-lattice minerals, moisture is absorbed not only on the outer surfaces, but also, as described above, between the lattice layers, thus causing the basal spacing to increase. In such clays, the adsorbed moisture may reach values of 10 to 20 per cent. at moderate humidities.

The relationship between moisture adsorption and vapour pressure in clays of different types has been studied by Vassiliou and White,[11, 12] who used their data to estimate the wettable surface areas of clays by use of the Brunauer, Emmett and Teller (B.E.T.) adsorption equation (see later). As might be expected, the calculated areas were much higher for montmorillonites, in which the interior surfaces are available to moisture, than for secondary micas or kaolinites, being of the order of 3 to 400 sq. m. per gm. for the former and 80 to 130 and 15 to 20 sq. m. per gm. respectively for the two latter. Ca-montmorillonite, however, gave greater moisture adsorption at low humidities than Na-montmorillonite, and consequently a higher calculated surface area. This latter effect has been observed by other investigators, *e.g.*, by Siefert and Henry[13]—who found that Ca clays, in general, adsorb water more strongly than Na clays, giving a higher heat of wetting—and by Mooney, Keenan and Wood,[14] who found that with alkali and alkaline-earth cations the moisture adsorption increased with increasing charge and decreasing size of the cation, *i.e.*, with increasing "strength" of the cation since the electrostatic potential of a cation, and the energy of the bonds it forms, are directly proportional to its charge and inversely proportional to its radius.

### Water and Montmorillonites

The relationship between the humidity and the moisture content and basal spacing of montmorillonites has been studied by many investigators. A point to note in considering their results is that, on the basis of the montmorillonite formula given earlier, an adsorption of 10 per cent. of the dry weight of the clay corresponds approximately to four water molecules per unit cell. If this goes entirely between the layers, *i.e.*, between pairs of Y sheets forming the water-layer surfaces, this is equivalent to four water molecules to every six oxygen ions in each of the Y sheets or one water molecule to every $Si^{4+}$ cation underlying

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each sheet. A moisture content of 10 per cent. would then correspond to complete coverage of all the "positive spots" on the interlayer surfaces caused by the presence of the underlying $Si^{4+}$ cations, since each water molecule would cover two positive spots, *viz.*, one on each of the Y sheets between which it lies. As pointed out by Hendricks and Jefferson,[15] this would correspond to the formation between the layers of a continuous sheet of water molecules having a hexagonal structure similar to that observed in certain forms of ice, and having a similar distance of separation between neighbouring molecules, *viz.*, about 3.0 Å. The thickness of such a film would be of the order of 2.5 Å., while a film two molecules thick would be about 5.0 Å., and so on.

Bradley, Grim and Clark[16] actually found that the swelling of montmorillonite took place in steps of this kind, though the number of water molecules per unit cell to form a sheet do not agree exactly with the above estimate. Thus, starting with an initial basal spacing of 9.6 Å. for the dry clay, spacings of 12.4, 15.4, 18.4 and 21.4 Å., equivalent to 1, 2, 3 and 4 sheets of water between the layers, were found at moisture contents corresponding to 6, 12, 18 and 24 water molecules per unit cell. Some authorities, however, *e.g.* Nagelschmidt[17] and Hofmann and Bilke,[18] have reported continuous variation of basal spacing with moisture content. According to MacEwan[6] this is probably to be attributed to the co-existence of water sheets of different thicknesses in different parts of the crystal.

The spacings observed are also affected by the nature of the exchangeable cations. Thus Mering[19] found that with Ca-montmorillonite the basal spacing increased immediately on hydration to about 14 Å. and remained at this value over an appreciable range of moisture contents. He attributed this large initial spacing, which is intermediate to the values expected for one and two water sheets respectively, to the formation, not of sheets, but of octahedral groups of six water molecules round each $Ca^{2+}$ ion. At higher moisture contents, the value rose to 15.4 Å., corresponding to double sheets, and finally to 17.9 and 21 Å. With Na-montmorillonite, the basal spacing increased continuously with moisture content, but the basal reflections obtained by X-rays tended to be diffuse, indicating some randomness in the spacing. His measured spacings were 16.2, 18.5 and 19.5 Å. at relative humidities of 90, 96 and 99 per cent., and moisture contents of 0.4, 0.6 and 1.0 gm. per gm. of clay. These spacings correspond to 2.2, 3 and 3.3 times the theoretical thickness of a single water sheet.

**Effect of Inter-layer Cations**

The manner in which the moisture adsorption and retention is influenced by the nature of the inter-layer cations was investigated by Hendricks, Nelson and Alexander[20], who found that with divalent cations of the alkaline-earth group metals, *viz.*, $Mg^{2+}$, $Ca^{2+}$, $Sr^{2+}$ and $Ba^{2+}$, the first stage of adsorption at low humidities was the formation of hydration shells of six water molecules round each cation, together with a layer of water one molecule thick on the surface of the clay not immediately contiguous to the cations. (At a charge deficiency of 0.66 units per unit cell requiring 0.33 divalent cations in the inter-layer space per unit cell, the number of water molecules held by the ions per unit cell would then be two, corresponding approximately to 5 per cent. water. The remaining water would be surface-adsorbed water.) With the Mg- and Ca-forms of Mississippi montmorillonite this stage was completed at 10 per cent. relative humidity and a moisture content of 12 per cent. to give a basal spacing of 13 to 13.5 Å. as compared to 12 to 13 Å. for an ideal single sheet. The clay then gave a double moisture peak on the thermal-analysis curve, an upper one at 240 deg. C., attributable to removal of the firmly-bound hydration shell round the cations, and a lower one at about 200 deg. C., due to removal of the surface water. At humidities of the order of 25 per cent. the basal spacing increased from 15 to 16 Å., corresponding to a double water layer, and a third still lower endothermic peak occurred. Similar results were obtained with Sr and Ba, but the temperatures of the two upper peaks were lowered by about 20 deg. C. due to the weaker bonding forces. Of the alkali-metal cations, only $Li^{+}$, the smallest, gave a high-temperature peak, attributable to the formation of a hydration shell containing three water molecules. With $Na^{+}$, $K^{+}$ and $Cs^{+}$, however, formation of the first water sheet gave only a single peak at 180 deg. C., so that no hydration of the ions was apparently occurring.

**Swelling Phenomenon**

The lattice swelling observed with montmorillonites in the presence of water is probably similar in its nature to the much smaller swelling observed when clays of the non-expanding type, such as kaolinites are mixed with water to bring them to the plastic state, except that in the latter case the swelling occurs between the particles only. In both cases, the effect apparently arises from the attraction of the exchangeable ions for water, which causes water to be drawn between the surfaces so that a swelling pressure is exerted. Measurements of this pressure have been made by Macey[21] and by Norton and Johnson[22] using a cylinder fitted with permeable pistons which permitted the passage of water but retained the clay. It was found that the pressure fell off with increasing water content and hence with film thickness according to an approximately exponential or hyperbolic relation. Schofield[23] has shown that this behaviour can be accounted for in terms of the osmotic activity in the water film of the exchangeable cations associated with the clay surfaces. The plastic and bonding properties of clay/water mixtures, which depend largely on the ability of the particles to surround themselves with relatively thick films of moisture, are thus directly related to the presence of the exchangeable cations.

An important feature of Na-montmorillonite, also related to this action of the cations, is that, when a large enough quantity of water is present, complete separation of the individual layers of the crystals apparently takes place. Evidence of this is provided by the fact that on progressive addition of water to the clay, the 20 Å. basal reflection ultimately dis-

appears without becoming larger, and by certain work by Schofield,[24] who found that the surface area in this condition corresponded to a particle thickness of only 18 Å., *i.e.*, to almost complete dispersion. With Ca- and H- montmorillonite this apparently does not happen, for basal spacings have been observed even when a considerable excess of water was present.[19] It is presumably this behaviour of Na-montmorillonite which is responsible for its very large gel-forming capacity as compared to the so-called " non-swelling " characteristic of Ca-montmorillonite. The term " non-swelling," is, however, a somewhat misleading one, since the lattice of Ca-montmorillonite does expand with water.

### (3) Effect of Heat on Clays

The changes which take place as clays are heated to progressively higher temperatures are as follows:

(1) Loss of adsorbed moisture associated with the external surfaces of the particles or present as films between the layers.

(2) Loss of the " structural " water present in the lattice as OH groups, this being accompanied ultimately by breakdown of the clay structure and formation of a highly-disordered or amorphous residue.

(3) Crystallization of γ-alumina or other spinel structures from the residue, followed by crystallization of silica as cristobalite and ultimate recombination of silica and alumina to form mullite ($3Al_2O_3.2SiO_2$).

(4) Ultimate fusion over a range of temperatures with progressive solution of the crystalline constituents in the liquid phase.

Of these, (1) and (2) can be followed by means of so-called dehydration curves determined by weighing the sample after static heating at various temperatures. (2), (3) and (4), and also (1) in the case of expanding lattice minerals (in which the basal spacing contracts as they lose inter-layer water), can be followed by X-ray (powder) photographs of heated samples. (1), (2) and the γ-$Al_2O_3$ (spinel) crystallization are the changes normally recorded on thermal-analysis curves, (1) and (2) taking place with adsorption of heat (endothermic effect) and the γ-$Al_2O_3$ crystallization with an evolution of heat (exothermic effect). A second exothermic peak observed with some clays at temperatures above that of the γ-$Al_2O_3$ peak (which is generally about 950 deg. C.) may be due to the crystallization either of cristobalite or mullite.[25] A point to note is that, since time is required for these reactions to proceed, the peak temperatures determined by thermal analysis, which involves a continuous rise of the temperature of the sample, are in general appreciably higher than are the corresponding transformation temperatures determined by methods involving static heating. Reaction (2) has been investigated from this point of view by Murray and White.[26]

Reaction (1), it will be noted, is merely a reversal of the adsorption reactions discussed in the previous section. With ordered kaolinite and other non-expanding minerals it involves only the loss of water held on the external surfaces of the clay particles and is generally essentially complete after drying at 100 to 110 deg. C. or lower, no change in structure being detectable. With hydrated halloysite, which contains sheets of water between the layers, most of this water is eliminated on drying between 75 and 100 deg. C.[2] The remainder, however, requires temperatures approaching 400 deg. C. for its complete removal. As the inter-layer water is driven off, the basal spacing shrinks from an initial value of 9.6 to 10.1 Å. to 7.2 Å. The disordered kaolinites found in fireclays appear to be intermediate in their behaviour to ordered kaolinite and halloysite, the bulk of the water lost occurring below 100 deg. C. with some further loss above this temperature. There is some evidence that the lattice contracts slightly during the process, but this is not very conclusive. With all these materials, the moisture-loss peak on the thermal-analysis curve occurs between 120 and 200 deg. C. depending on the heating rate and the type of apparatus employed.

With expanding-lattice minerals, such as montmorillonite, drying is accompanied by elimination of the inter-layer water and contraction of the basal spacing from 12 to 15 Å. (in material which has been exposed to the atmosphere) to about 10 Å., the exact value depending on the nature of the inter-layer cations.[6] In most cases the bulk of this water loss occurs below 100 to 110 deg. C.

With cations such as those of the alkaline-earth metals, however, which form firmly-held hydration shells of water molecules round them, higher temperatures are necessary for complete removal of this water, *e.g.* vermiculite, which has $Mg^{2+}$ cations between the lamallae, loses about half of its inter-layer water at 110 deg. C. and the remainder at higher temperatures.[27] As already indicated, this " hydration water " gives rise to an additional peak in the region of 200 to 240 deg. C., depending on the nature of the cations on the thermal-analysis curve.

In most cases, these changes are completely reversible up to about 200 deg. C., but at higher temperatures fixation of the ions tends to occur, *i.e.*, they become bonded to the lattice with a consequent decrease in base-exchange capacity and in the ability to expand. The extent to which this occurs at low temperatures depends on the nature of the cations, *e.g.*, $Li^+$ tends to become fixed on heating even at 200 deg. C., while with $K^+$ the fixation begins at even lower temperatures. Such behaviour is obviously important from the point of view of the retention of bonding properties after heating.

### Loss of Constitutional Water

The loss of constitutional water proceeds over a range of temperature which varies with the nature of the clay mineral. Thus, according to published dehydration curves, the loss under static heating conditions occurs mainly over the range 450 to 550 deg. C. with ordered kaolinite, from 350 deg. C. or lower to 550 deg. C. with illites, and from 5 650 deg. C. with montmorillonites of the 5/2 ty With the montmorillonites of the 3/2 beidellite-nontronite type, the loss appears to begin at an appreciably lower temperature (see later). The corresponding peak temperatures on differential thermal-analysis curves are, of course, higher than these temperatures.

The factors determining the break-up temperature

*Effect of Heat on Clays*

are incompletely understood, but it appears to be affected by particle size, chemical composition and structure. Thus in the clays of the kaolinite group, as pointed out by Richardson,[28] the decomposition temperature is lowered when the lattice is disordered, *e.g.*, the endothermic peak temperatures of china clay, fireclay and halloysite are 583 deg. C., 550 to 562 deg. C. and 550 deg. C. respectively, while dickite, with a more highly-organized structure than kaolinite, gives a peak approximately 100 deg. C. higher than the latter. With all these minerals, the theoretical loss is 14 per cent. of the dry weight of the clay.

In montmorillonites, micas and illites, the decomposition temperature appears to be influenced by the cations within the lattice proper. This aspect has been discussed by Page[28] who concludes that replacement of $Al^{3+}$ by $Mg^{2+}$ in the octahedral positions raises the decomposition temperature, whereas replacement of $Al^{3+}$ by $Fe^{3+}$ in these positions or of $Si^{4+}$ by $Al^{3+}$ in the tetrahedral positions lowers it. While these conclusions do not perhaps fit all cases, they are consistent with the low dehydration temperatures observed with illites, which contain substitutional $Al^{3+}$ in the tetrahedral positions, and with members of the beidellite-nontronite series which have a similar replacement of $Si^{4+}$ by $Al^{3+}$ and also, generally, partial replacement of $Al^{3+}$ by $Fe^{3+}$ in the octahedral positions.

There appears to be no evidence that the breakdown temperature is affected by the exchangeable, inter-layer cations. Mering,[19] however, observed that with Ca-montmorillonite the first loss of lattice water was accompanied by a tendency of the clay particles to bond together due to the formation of permanent "ionic bridges" between the edges of neighbouring particles. This caused a decrease in the adsorption capacity, but left the ability of the lattice to expand unaffected. Only at high degrees of dehydration was the swelling capacity destroyed due to the formation of permanent linkages between the sheets. With a Na-montmorillonite, on the other hand, the adsorption capacity was unaffected during the early stages of dehydration, no permanent linkages being formed until a considerable degree of dehydration had occurred. Such linkages when they formed did so between the particles and between the layers indiscriminately.

**Thermal-analysis Curves**

Typical thermal-analysis curves for clays of different types, including the clays used in the present investigation, are shown in Fig. 1. Features of these, which aid in the characterisation of the clays, are :—

(1) The magnitude of the low-temperature moisture-peak of the air-dried clay, which reflects its the relative adsorptive power for moisture. Halloysite, if hydrated gives a large moisture-peak.

(2) The temperature of the dehydration peak and its magnitude and shape, *e.g.*, kaolinitic clays and halloysite give larger and sharper peask than bentonites and secondary mica clays corresponding to their larger content of $OH^-$ water, and their rather narrow decomposition range. Both the halloysite and the secondary mica give peak temperatures lower than that of the china clay, the ball clay being intermediate, indicating, apparently, a disordered kaolinite. The bentonites will be seen to be of two types, those which give a single peak in the region of 670 to 690 deg. C. and those which give two peaks, the lower at about the same temperature as the secondary mica (Pembina bentonite is exceptional in this respect in giving a peak at 390 deg. C.) and the upper in the range 630 to 665 deg. C.

(3) The occurrence of a third endothermic peak at 890 deg. C. on the curves of the bentonites, which is considered to represent the final collapse of the dehydrated lattice. Another view, attributed to McConnell,[29] is that it represents the break-up of tetrahedral $(OH)_4$ groups which he considers can replace $SiO_4$ groups in the lattice.

(4) The magnitude and the shape of the $\gamma$-$Al_2O_3$ exothermic peak in the range 950 to 1000 deg. C. This is biggest and sharpest with the china-clay and halloysite, corresponding to their high-alumina content. It is known that the presence of alkalies and certain other fluxes tends to lower the temperature of this point and to diminish it or make it disappear entirely. This is consistent with its poorly-defined character or absence in the bentonites and secondary mica.

Additional features that may be noted are the occurrence of exothermic effects, probably due to organic matter, in the range 200 to 400 deg. C. on the curves of the ball clay and secondary mica clay, and a small endothermic peak on the curve of the halloysite, which is due to the presence of a small amount of gibbsite ($Al_2O_3.3H_2O$) in this clay.

**PART II**

(1) Clays Investigated in Present Work.

At the outset of the work, the desirability of including in the investigation clays representing all the principal clay-mineral types was realised. A clay of the secondary mica type it had been intended to use, however, was found on examination to contain a very appreciable proportion of calcite and was, therefore, omitted. Again, in view of the emphasis on the use of bentonite in foundries and since it was known that considerable differences in "life" occurred between bentonites from different sources, it was considered essential to study as many materials of this type as possible. Finally, when it became clear from work in the Refractories Department of Sheffield University involving the routine examination of bonding clays from many sources that the bentonites examined fell into two groups (*viz.*, those which gave a single dehydration peak and those which gave two) it was decided to include three of each type in the work. On purely *a priori* grounds it seemed likely that the occurrence of a low-temperature peak indicating decomposition at low temperatures might be associated with a tendency to shortness of life.

The clays finally selected for investigation are shown with their chief chemical and physical properties in Table I. They comprise two kaolinitic clays, a commercial china clay and a ball clay, and the six bentonites. The thermal-analysis curves of all these clays are included in Fig. 1. The chemical analyses were determined using normal methods, and

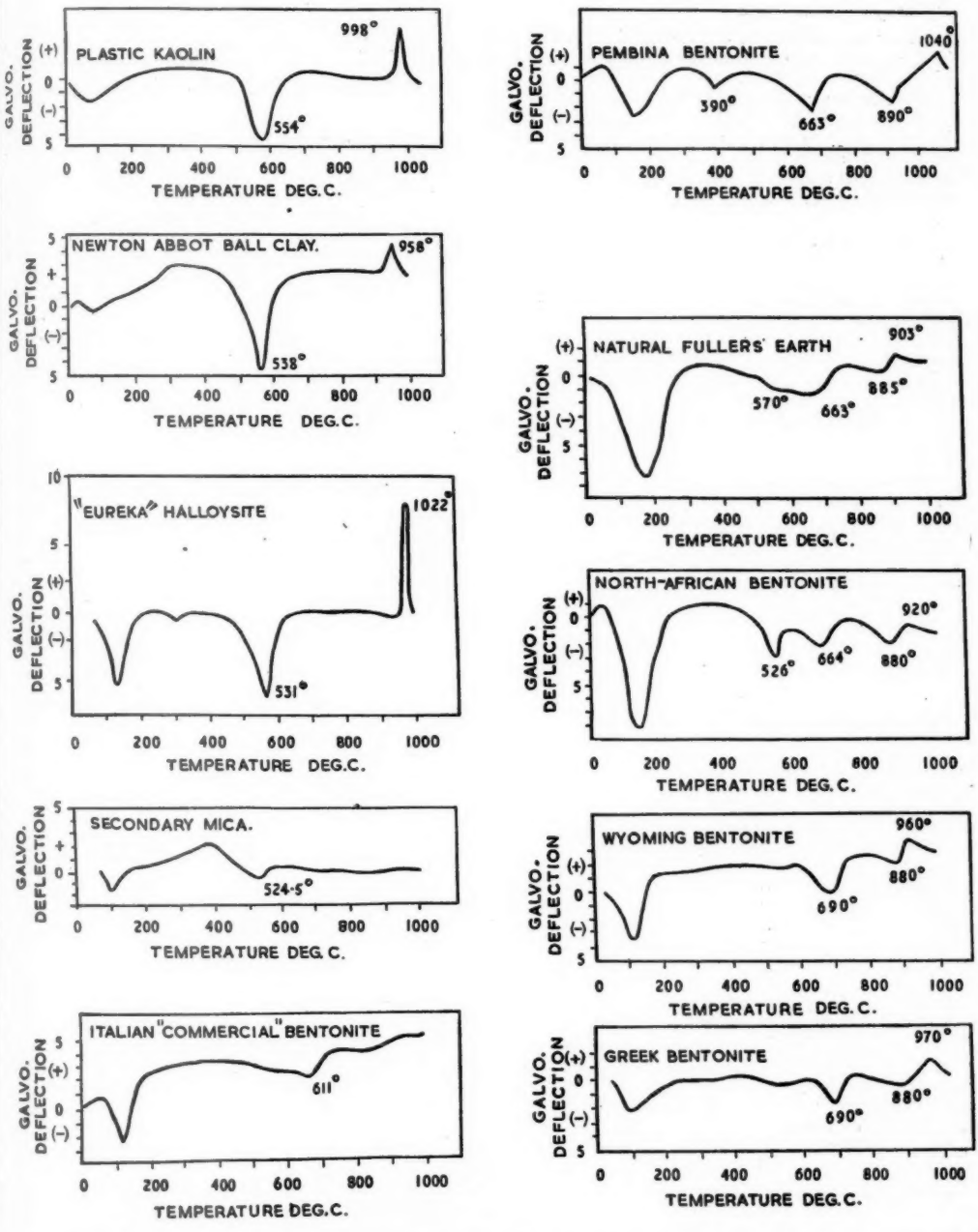


FIG. 1.—*Differential Thermal-analysis Curves of Various Clay Minerals for a Heating Rate of* 10 *deg. C. per min., and a Galvanometer Series Resistance at* 202 *ohms for Bentonites, Kaolin, Ball Clay, and Secondary Mica, and* 450 *ohms for Halloysite. The Weight of Sample taken was approximately* 1.2 *gm. for Bentonites and Secondary Mica,* 0.7 *gm. for Kaolin and Ball Clay, and* 1.6 *gm. for Halloysite.*

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moisture losses by drying at 110 deg. C. and 250 deg.C. The methods used in determining the remaining properties were as follow :—

*Base-exchange Capacity :* The method used was that described by Graham and Sullivan,[30] which involves repeated leaching with ammonium acetate in absolute alcohol, followed by washing in 80 per cent. alcohol and determination of the exchangeable ammonia by distillation in 30 per cent. NaOH solution.

*Gelling Index :* The method used was that described by Henderson.[31] A known weight of the clay is added to 10 ml. of distilled water in a test-tube which is well shaken and left overnight. The minimum amount of clay to give a gel which will then not flow out of the tube when it is inverted is a measure of the gelling capacity, the gelling index being expressed as the value of the ratio weight of water : minimum weight of clay. Clays with a gelling index of less than 8·3 are classed as " non-swelling."

*pH of Suspension :* pH values were determin e on suspensions containing 1.5 gm. clay in 100 l. d distilled water, (*a*) after mixing and shaking up for a few minutes (*b*) after leaving to stand overnight. This procedure was adopted, since, with some clays, the pH changes appreciably when the suspension is allowed to stand.

*Fusion Points :* These were carried out on miniature cones heated in air in a platinum furnace at 10 deg. C. per min., temperatures being taken by means of a platinum-13 per cent. rhodium/platinum thermocouple with its junction placed alongside the cone.

*Constitution :* The constitution was deduced mainly from the thermal-analysis curves and from the results of microscopic examination of the powdered clay when immersed in various liquids of known refractive indices. X-ray methods were not used, as a " clay camera " was not available. The conclusions reached are, however, in substantial agreement with the results of X-ray and electron-microscope examination carried out later by the British Ceramic Research Association (private communication).

In classifying the clays, the following features were regarded as significant :—

1. The high potash content of the kaolin and ball clay are consistent with the indications that they contain sericite or secondary mica.

2. The thermal analysis curves of the Italian and Greek bentonites resemble those of Wyoming bentonite, a 5 : 2 montmorillonite, in giving a single dehydration peak at 670 to 690 deg. C. (though there is some evidence of an endothermic effect below the peak with the Italian material). The Pembina and North-African bentonites and the Fullers' Earth all give a double peak, a feature

TABLE I.—*Characteristics of the Clays Investigated.*

| — | " Plastic " kaolin. | Newton Abbot ball clay. | Wyoming bentonite. | Commercially-treated Italian bentonite. | Greek bentonite. | Pembina bentonite. | North-African bentonite. | Natural Fullers' Earth. |
|---|---|---|---|---|---|---|---|---|
| Hygroscopic moisture as stored per cent. (by drying at 110 deg. C.) | 1.3 | 1.7 | 10.5 | 9.6 | 12.3 | 16.8 | 13.6 | 13.0 |
| Moisture loss between 110 and 250 deg. C. (per cent. of dried weight) | 0.2 | 1.1 | 0.7 | 0.8 (Samples dried at 110 deg. C.) | 1.6 | 2.4 | 2.3 | 1.4 |
| Chemical analysis, per cent.— | | | | | | | | |
| Loss on ignition (1,000 deg. C.) | 12.68 | 11.61 | 6.29 | 5.82 | 6.12 | 11.27 | 7.60 | 9.79 |
| $SiO_2$ | 47.21 | 51.97 | 63.09 | 72.15 | 73.07 | 56.42 | 58.90 | 57.35 |
| $TiO_2$ | trace | 1.19 | 0.28 | 0.20 | 0.24 | 0.70 | n.d. | 0.72 |
| $Al_2O_3$ | 37.00 | 31.64 | 18.62 | 14.30 | 13.84 | 21.17 | 19.60 | 19.81 |
| $Fe_2O_3$ | 0.71 | 1.26 | 5.42* | 1.74 | 1.64 | 4.63 | 5.20 | 6.56 |
| MnO | nil | nil | trace | trace | trace | trace | n.d. | trace |
| CaO | 0.43 | 0.41 | 1.62 | 1.19 | 0.76 | 1.91 | 2.60 | 2.72 |
| MgO | 0·07 | 0.34 | 2.22 | 2.01 | 1.93 | 2.73 | 1.80 | 3.20 |
| $K_2O$ | 1.22 | 1.58 | 0.22 | 0.46 | 0.32 | 0.22 | n.d. | trace |
| $Na_2O$ | trace | 0.04 | 1.76 | 1.76 | 1.06 | 0.52 | n.d. | trace |
| Total | 99.32 | 100.04 | 99.52 | 99.63 | 98.98 | 99.57 | — | 100.15 |
| $SO_3$ | n.d. | n.d. | n.d. | n.d. | 1.02 | n.d. | n.d. | n.d. |
| 2 × Si : Al | 2.16 | 2.75 | 5.75 | 8.53 | 8.98 | 4.53 | 5.1 | 4.9 |
| Base-exchange capacity, m.-e. per 100 gm. raw clay | 9.47 | 11.25 | 74.3 | 57.2 | 44.32 | 95.27 | 96.8 | 76.7 |
| pH of suspension (after standing 24 hours) | 5.89 | 6.10 | 8.70 | 8.54 | 5.44 | 4.40 | 8.99 | 7.00 |
| Thermal analysis (dehydration peak, 4 deg. C.) | 554 | 538 | 688 | 671 | 690 | 390 and 663 | 520 and 663 | 632 |
| Gelling index | Non-swelling | Non-swelling | 16.7 | 16.7 | Non-swelling | Non-swelling | Non-swelling | Non-swelling |
| Fusion points on miniature cone (cone tip down, deg. C.) | — | — | 1,360 | 1,310 | 1,320 | 1,330 | 1,380 | n.d. |
| Constitution : | | | | | | | | |
| Clay mineral | Kaolinite | Degraded kaolinite | Na-montmorillonite | Na-montmorillonite | Montmorillonite | Ca-montmorillonite | Ca-montmorillonite | Ca-montmorillonite |
| Chief impurities | Sericite or sec. mica | Sec. mica quartz | Quartz, trace calcite | Quartz, trace calcite | Cristobalite† and a little quartz, trace calcite, probably gypsum | Quartz, calcite | Quartz, calcite | Quartz, calcite |

* This is an abnormally high iron-oxide figure for this type of bentonite. n.d. Not determined.
† Apparently present as an impurity. Identified by X-ray examination by British Ceramic Research Association.

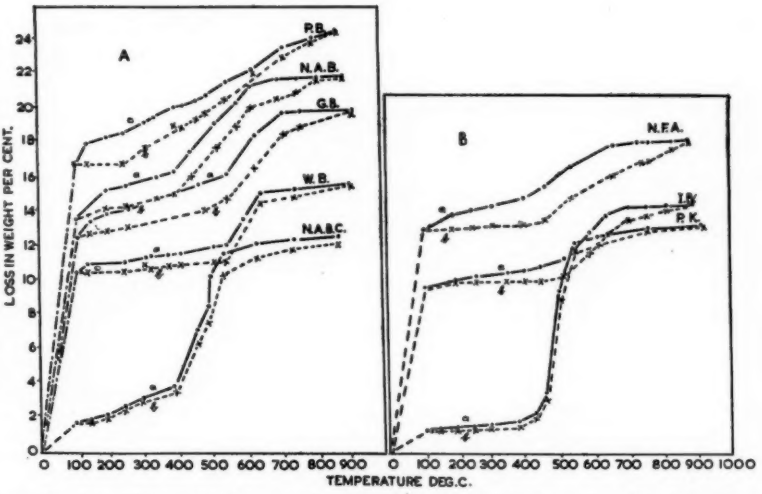


FIG. 2.—*Loss of Weight of Clays, (A) after Heating to Various Temperatures, (B) after Heating to Various Temperatures followed by Re-wetting and Drying at 110 deg. C. Pembina Bentonite (P.B.); Wyoming Bentonite (W.B.); Newton Abbot Ball Clay (N.A.B.C.); and Greek Bentonite (G.B.). Natural Fullers' Earth (N.F.A.), Italian Bentonite (I.B.), and Plastic Kaolin (P.K.).*

which work in the University has shown to be generally associated with bentonites of low Si : Al ratio and high iron content as in the present case.

3. The high gelling index of the Wyoming and Italian bentonites is associated with a low moisture loss between 110 and 250 deg. C. and moderate loss at 110 deg. C. The remaining montmorillonitic clays are non-swelling and give high moisture losses at 110 deg. C. and between 110 and 250 deg. C. The former properties are consistent with the presence of Na and the latter with the presence of Ca as the predominant exchangeable cation. An attempt to determine the cations present in the ammonium acetate leachates from Wyoming and Pembina bentonites gave the following results :

| | Wyoming bentonite. m.-e. per 100 gm. | Pembina bentonite. m.-e. per 100 gm. |
|---|---|---|
| Ca | 8.8 | 23.8 |
| Na | 42.4 | 3.46 |
| Mg | 19.9 | 1.2 |
| K | 3.2 | 10.1 |
| | 74.3 | 48.5 |

The total base exchange capacity of Wyoming bentonite (see Table I) agrees well with the (earlier sum of the exchangeable Ca, Mg, Na and K contents, but that of Pembina bentonite is much higher than the sum of the separate cations. The difference in the two values obtained is assumed to be due to the presence of exchangeable hydrogen, which of course cannot be determined in the ammonium-acetate leachates.

(2) DEHYDRATION CHARACTERISTICS.

As a preliminary to the investigation of the changes in properties of the eight clays due to heating, their dehydration curves (*i.e.*, moisture-loss/temperature curves) were determined by weighing after heating to constant weight at various temperatures from 110 deg. C. upwards. The curves obtained are shown in Figs. 2 (A) and (B) (continuous curves marked *a*). Except in the case of Pembina bentonite, each curve has two principal ranges of moisture loss, the first up to 110 deg. C. corresponding to the loss of the bulk of the adsorbed moisture and the second to loss of OH water as the clay decomposes. The decomposition ranges are approximately as follow :—

| Kaolinitic clays. | | Montmorillonitic clays. | |
|---|---|---|---|
| | | Group (*a*). | |
| China clay | 450 to 500 deg. C. | Wyoming bentonite | 550 to 650 deg. C. |
| Ball clay | 400 to 500 deg. C. | Italian bentonite | 550 to 700 deg. C. |
| | | Greek bentonite | 550 to 700 deg. C. |
| | | Group (*b*). | |
| | | Fullers' earth | 400 to 650 deg. C. |
| | | North-African bentonite | 400 to 600 deg. C. |
| | | Pembina bentonite | Continuous loss from 110 deg. C. |

The low decomposition temperatures of the two kaolinitic clays are, of course, to be expected. Of the montmorillonitic clays, it will be seen that those of group (*b*) start to decompose at a considerably lower temperature than those of group (*a*).

In addition to the losses in these two ranges all the clays tend to lose weight progressively to some extent between 110 deg. C. and the decomposition range. Up to 200 to 250 deg. C., as has already been indicated (Table I), the magnitude of this loss appears to depend on the amount and nature of the exchangeable cations and is greatest with the non-swelling montmorillonites of group (*b*). The progressive loss in weight above 250 deg. C., however, is apparently due to the elimination of the more loosely held OH-water, possibly from the edges of the particles where considerable disturbance in the crystalline lattice is likely. In the case of the ball clay some of this loss would represent organic matter. In the case of the other clays the curves indicate that the amount of such loosely-held water varies considerably from clay to clay, being least in the relatively coarsely crystalline china clay, and the Wyoming and Italian bentonites (which show only slight losses between 250 deg. C. and the dehydration range) and greatest in Pembina bentonite.

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**Re-wetting Treatment**

To obtain further insight into this phenomenon, the various samples were reweighed after wetting and drying at 110 deg. C. This treatment it was thought would restore the water of hydration of the cations (so long as these were not rendered inert by the heat-treatment) but might not restore lost OH-groups, so that the onset of the loss of OH-water might be detectable. The results obtained, shown by the dashed lines (marked *b*) of Figs. 2 (A) and (B), show that permanent loss begins with most of the clays at relatively low temperatures, being most marked with the Pembina bentonite and least with the Wyoming and Italian bentonites, the fullers' earth and the china clay.

It will thus be evident that no simple correlation exists between the loss of loosely-held OH-water and the grouping of the montmorillonites. One possibly significant feature is that the divergence between the two curves is greatest in the case of the non-swelling montmorillonites. While at low temperatures this divergence is attributable to hydration of the exchangeable cations in these clays, the reason for its continuance up to and above the dehydration temperature, when fixation of these cations should have occurred, is less obvious and suggests that as the clay decomposes hydratable products are formed, which, for these clays at least, are apparently related to the nature of the exchangeable cations. This behaviour may, however, be related to the nature of impurities present since, when the secondary mica clay containing a considerable quantity of calcite was examined in this way, it was found that the divergence between the two curves increased with increasing temperature to over 900 deg. C. due to liberation of CaO.

*(To be continued)*

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# Heat Conductivity of Moulding Materials

Dr. D. V. Atterton has summarized his conclusions of a paper on the above subject printed in the *Journal* of the Iron and Steel Institute by the following statement:—

(1) The apparent thermal conductivities of compacts of bentonite-bonded silica sands are of similar values (about 0.002 c.g.s. units) at room temperatures, where the mechanism of heat transfer is virtually only by true thermal conduction. Increase of temperature up to about 600 deg. C. causes a decrease in apparent thermal conductivity, owing to a decrease in the true thermal conductivity of silica. Between 600 deg. and 1,300 deg. C., the conductivity increases in a linear manner with the cube of the absolute temperature, owing to the onset and eventual predominance of heat transfer by intergranular and transgranular radiation. Beyond about 1,300 deg. C. the apparent thermal conductivity values are less than those predicted by the cubic equation, and this is probably due mainly to reduction in the heat transferred by transgranular radiation consequent upon chemical reaction and sintering in the sand.

(2) For Leighton Buzzard sand compacts, the apparent thermal conductivity markedly increases with increase of sand grain-size, particularly at high temperatures where radiation effects are appreciable. However, for sands from different deposits (*e.g.*, Leighton Buzzard and Chelford sands) it seems that the apparent thermal conductivity at high temperatures is more dependent upon the chemical composition of the sands, which probably influences their transparency to heat radiation.

(3) Increase of compact density and of binder content of bentonite-bonded silica sands increases the apparent thermal conductivity, particularly at low temperatures, and this is probably due mainly to an increase in the area of contact between the grains for true thermal conduction.

(4) The apparent thermal conductivity of a zircon sand and its variation with temperature over the range 20 to 1,550 deg. C. are similar to those of silica sands.

(5) Olivine-sand compacts have apparent thermal conductivity values that are similar to those of silica sands at low temperatures; but their variation with temperature is considerably less, and this has been explained by a reduction in the heat transfer by transgranular radiation consequent upon the formation, by chemical reaction, of materials relatively opaque to heat radiation.

(6) The apparent thermal conductivity of the sinter of an exothermic feeding material is lower than those of most sands at steel casting temperatures.

(7) The apparent thermal conductivity of a plaster material, such as that used for insulating feeder heads for non-ferrous castings, is very low (about 0.0005 c.g.s. units), but it increases quite rapidly with temperature beyond about 900 deg. C.

*(References continued from col. 1)*


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# Auto-slagging Twin Tuyeres

[*Slightly abridged*]

*This anonymous article in* Fonderie *deals with modifications to twin tuyeres to increase their efficiency. In France, twin tuyeres are very common, for they avoid the necessity of closing entirely one blocked tuyere to clear it from slag as is usually the habit in this country. As coke has deteriorated in this country in the last decade, it is obviously worth while to study French results.*

As long ago as 1870, there was incorporated in the Krigar cupola a system of self-slagging tuyeres, which functioned by operating a damper from the outside of the wind belt by means of screw and handle. According to the designer, this system eliminates the de-slagging of the tuyeres by poking, and does, it is apparent from the drawings, bring about tuyere clearance quite automatically. It is not a matter of having twin tuyeres, but simply the alternate closing of the normal tuyeres for the re-distribution of blast.

Many systems have been used since then, and a number of foundrymen have found solutions to the problem, often of an original and effective type. Leaving the historical side, this article will deal solely with a few worthwhile advances.

### Simple and Twin Tuyeres

The zone of the cupola where the tuyeres enter is cooled by the cold blast brought in by the fan or blower. This results in a local solidification of the slag, which frequently leads to a progressive obstruction of the nose of the tuyere and blast can only with difficulty penetrate into the interior of the cupola. This increases the pressure indicated by the measuring apparatus, and in extreme cases the volume of the blast admitted into the cupola markedly decreases, so lowering the hourly melt. The phenomenon is well known in the conventional cupola, where the normal remedy is to clean out the slagged-up tuyere by means of a poker bar. This operation always introduces a number of drawbacks, of which the obvious are listed:—(1) The resulting shock can disturb the lining; (2) at tuyere level, the coke is broken into small pieces, and because of this presents increased resistance to the passage of the blast; (3) the opening of the tuyere introduces blast-loss and upsets the regular working; and (4) clearing a tuyere is an arduous job which can cause accidents.

On the other hand, any system whereby the input of air can be arrested through the slagged-up tuyere, results in the coke becoming incandescent and melting of the slag curtain and the tuyere thus cleans itself. However, the number of the tuyeres, and especially their total area, having been calculated in relation to the blast input to bring about proper combustion of the coke, any alteration tending to reduce the number in service can only be prejudicial to optimum working of the furnace. This naturally leads, therefore, to envisaging the replacement of the tuyere which is temporarily out of order, by a twin tuyere incorporated for alternative use and doing so without stopping the melting to any significant extent, using either one or other of the pair. The principle of twin auto-slagging tuyeres can solve this problem, as is well known, and the method has been adopted by a number of founders.

### Installation and Operation

To reduce local burn-out of the cupola lining and to avoid chilling the slag at the outlet of the obstructed tuyere by the blast from the tuyere in service, a layout is provided; a distance of at least 4 in. is arranged between each tuyere. An obvious solution would seem to be equidistant division of the circumference at the same level as the line of tuyeres, retaining the minimum spacing referred to. This layout ensures equable division of the blast, and in consequence, an even wear of the lining. Table I is a guide for determining the number of the groups of tuyeres to use according to the diameter of the cupola.

TABLE I.—*Tuyeres Needed for Various Cupola Diameters.*

| Internal diameter of cupola (in.). | Number of groups of tuyeres. |
|---|---|
| 20 to 22 | 2 or 3 |
| 24 | 3 |
| 26 ; 28 or 30 | 3 or 4 |
| 34 ; 36 ; 38 or 40 | 4 or 5 |
| 44 ; 48 or 52 | 5 or 6 |

The most rational use of the auto-slagging system is that which does not wait until a tuyere is slagged up, but arranges alternate opening and closing regularly, according to a predetermined plan (say, every 10 min., for example).

Further detail is the affair of specialized designer or users, except for the suggestion that it is not difficult to arrange for a method for the operator to change over all the tuyeres simultaneously. However, attention should be drawn to the fact that to obtain a proper de-slagging action, the closure of the idle tuyeres must be really blast-tight; this implies precision in the construction and assembly of the plant.

### Wind Boxes and Blast Supply

Before going on to detail the various arrangements designed for orderly operation of the slagging tuyere, it is helpful to deal first with the overall blast distribution to the cupola. First of all, it is necessary to differentiate between cupolas provided with high and low wind boxes. In the former system, the wind box is much above the tuyere level, and feeds the latter by vertical piping;

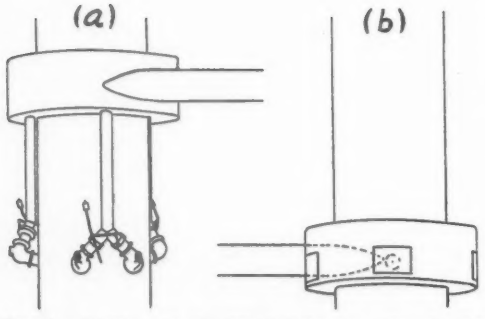


FIG. 1.—*Position of the Wind Belts in a Cupola; (a) High Wind Belt with Divided Tuyeres, and (b) Low Wind Belt of Orthodox Design.*

the tuyeres and the arrangements for twinning, being independent of the wind box, are therefore easily accessible. In the second system (low wind belt), the tuyeres are set inside the wind belt, and any arrangement envisaged must necessarily be incorporated. This, of necessity, rules out some solutions of the problem, as it generally does not allow of equidistant spacing of the tuyeres which is recommended, and necessitates lateral openings on the outside of the belt for installation and maintenance of the mechanism. Fig. 1 (*a*) and (*b*) shows the types of equipment for high and low wind belts. It should be noted that the high wind belt leads to a better distribution of the blast in the tuyeres, provided always that the following principles of construction have been taken into account: (*a*) That the blast mains bring the air tangentially to the wind belt and (*b*) that the dimensions conform to those given in the *Journal d'Informations Techniques** (which details the blast requirements corresponding to melting rates). Because of the better distribution of the blast there is no one tuyere taking more than the others; the melting zone receives its properly balanced air supply and remains virtually symmetrical, thereby improving the running of the plant—and the wear of the lining remains regular along all the circumference.

Endeavours have been made in some cases to find a still better method of controlling the output of the various down-pipes from the wind belt to the tuyeres, by the operation of valves located in the down-pipes; they are used for initial control in starting up the plant, and are then set at the positions then determined. However, in all cases where the essential principles of construction have been properly considered, and with no other control, the air delivery of the down-pipes is never sufficiently abnormal to create any irregularity in the working of the cupola or any inequality in the wear of the lining. In the author's opinion, therefore, valves between the wind belt and the

* *Caracteristiques des Cubilots* (Cupola dimensions). *Journal d'Informations Techniques des Industries de la Fonderie*, No. 42, October, 1952.

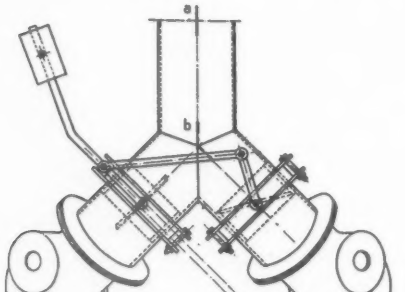


FIG. 2 Linked.—*Butterfly-valve Shut-off System for Auto-slagging Tuyeres of a High Wind Belt.*

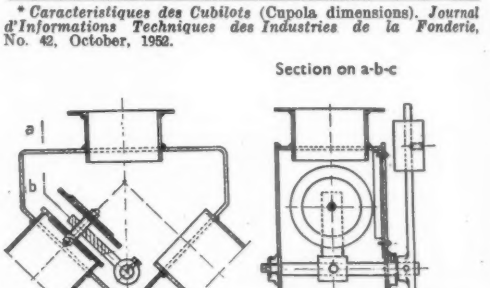


FIG. 3.—*Shutter-type Valve Isolating System for Auto-slagging Tuyeres enclosed in a Tuyere Box.*

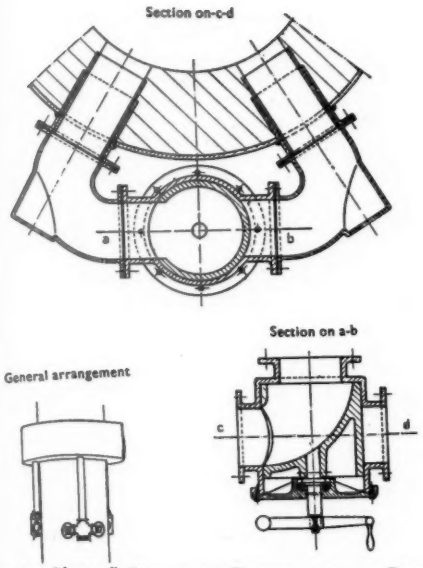


FIG. 4.—*Shut-off System for Tuyeres, using a Dome Valve installed vertically.*

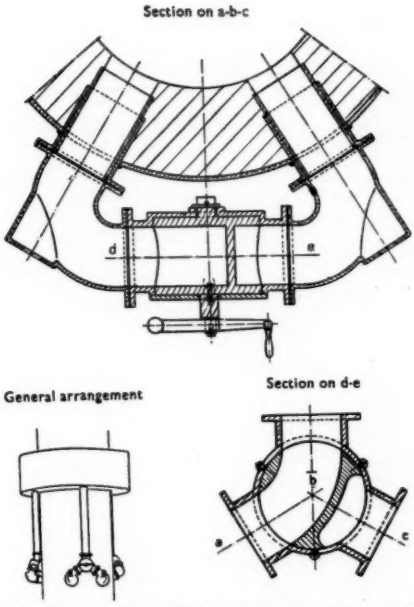


FIG. 5.—*Tuyere Shut-off System incorporating a Dome Valve in the Horizontal Plane.*

tuyeres are not essential. For the important advantage of a regular output and the consequences thereof, and for allowing the greatest latitude in the choice of tuyere design, as well as maximum accessibility, it is obviously best to specify a high wind belt for new cupola plant.

For existing cupolas having a low wind belt and envisaging their conversion to incorporate twin tuyeres, it is thought that it may be better to consider installing a high wind belt, because the improvements obtained thereby, though difficult to estimate monetarily, should be sufficient in most cases to enable the costs involved to be written off. This argument becomes more forceful when one encounters—as is not infrequently the case—badly worn wind belts, having significant air leakage and, which, because of their condition, really need replacement. In estimating costs, before taking a decision, it must be remembered, however, to take into consideration the re-installation of all the blast system. Despite what has been said, it is not necessary for a high wind belt to be placed near to the charging platform. In principle, all that is necessary is to allow a sufficient height between the bottom of the belt and the tuyere level to permit the installation of the auto-slagging device.

### Types of Twin Tuyeres

The author henceforth confines his remarks on layouts to cupolas served by a high wind belt.

*"Butterfly" Tuyere Valves.*—This arrangement, shown in Fig. 2, is based on the movement of "butterfly" valves in two directions. Its operation is carried out in such a way that the flow of the blast to one tuyere is stopped whilst the other is open, using a crank for changing over.

To ensure proper blast tightness, it is necessary that the cast-iron piping carrying the butterfly is machine-finished to fit accurately, and that the butterfly be pivoted on an assembly in line with its "closed" position. Satisfactory closure having been arranged, it is necessary to have relatively thick flaps (those made from thin sheet are unsatis-

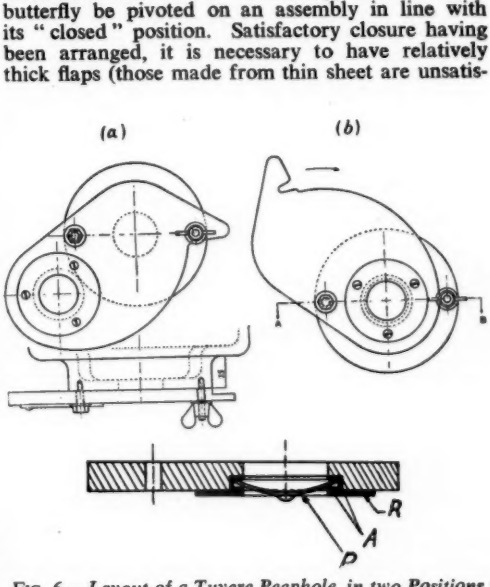


FIG. 6.—*Layout of a Tuyere Peephole, in two Positions; (a) Closed and (b) Open. The lower sketch shows the Detail of a Tuyere Inspection Cover.*

*Auto-slagging Twin Tuyeres*

factory). Moreover, it is necessary—and this goes for the whole equipment—to see that the mechanical system is such that there is no risk of a valve sticking.

*Shutter Valve.*—In the system shown in Fig. 3, a double-sided shutter, mounted in a tuyere box and turning on an axis, by splitting the piping into two, can alternately close one or other of the outlets. Here, again, a good surface finish and proper orientation of the edges of the flap in respect of the piping are necessary to ensure a blast-tight closure.

*Rotary Tuyere Valve.*—It would appear that this third system gives a better guarantee of blast tightness than the first two. It is obvious that the body of a three-way "rotary" valve can be constructed in two ways; *i.e.*, with a vertical rotary axis as in Fig. 4, and with a horizontal rotary axis as in Fig. 5.

**Recommendations**

A tuyere in course of being de-slagged obviously no longer receives an air supply from the outside, since it is under internal pressure from the hot blast inside the cupola. Because of this, two precautions should be taken:—(1) Not to stand in line with the peephole when opening any such tuyere, because one can receive—at a time when the opening is subjected to reverse blast—a serious burn from hot gases escaping from the cupola; and (2) to provide a set-up for the peepholes which gives two positions, as is shown in Fig. 6. Normal peephole windows seldom withstand the heat from the tuyeres while they are being cleared, and the system illustrated provides not only for a special Pyrex glass, but it also permits the clearing of a metallic obstruction when the tuyere can no longer be seen.

Precautions to take to avoid risk of explosion in the wind belt, the piping or the tuyere box (although such occurrences are very rarely met with) should be as follows. When blast is stopped during melting, the combustion of the coke is incomplete, and produces carbon monoxide which can penetrate into the parts mentioned. As the mixture of carbon monoxide and air can, at certain concentrations become explosive, explosions in the parts detailed may occur on re-starting. All cupolas carry such risks whether or not they are furnished with twin tuyeres, but this occurrence can be averted if the precaution be taken to open the operative tuyere peepholes at the beginning of every stoppage in blowing. The peepholes are closed immediately after the starting-up of the fan or blower, until the air has purged the system of any combustible gases.

## I.V.E. Annual Conference

The annual conference of the Institute of Vitreous Enamellers will be held this year at the Town Hall, Cheltenham Spa, from September 30 to October 3, the programme being as follows:—

*Wednesday, September* 30.—Evening—Civic Reception by the Mayor of Cheltenham.

*Thursday, October* 1.—Morning—Annual general meeting. Afterwards members will proceed to Oxford by motor coach to visit the Pressed Steel Company, Limited. Luncheon by invitation of the company. Evening—Members and guests will participate in a theatre visit.

*Friday, October* 2.—Morning and afternoon—Technical sessions. Evening—Annual dinner and dance.

*Saturday, October* 3.—Morning—Technical sessions and "question box" feature.

Members are advised to make their own hotel reservations as soon as possible to avoid disappointment. It is hoped that it will be possible for some overseas members and their guests to attend, and all members will look forward to the opportunity of renewing many pleasant friendships formed at previous conferences.

A programme of ladies' visits is being arranged, but details are not yet available.

The programme of technical sessions includes the following papers:—"Recent Developments in the Technology of Porcelain Enamelling on Steel in the United States," by Mr. E. Hommel; "Economics of Pickling and Pickle Liquor Disposal," by Dr. P. de Lattre, and "Recruitment and Training in the Enamelling Industry" by Mr. Callaghan and "Survey of the Vitreous-enamelling Industry in Denmark, Finland and Sweden," by J. H. Gray, A.I.MECH.E.

*I.V.E. Conferences,* 1954.—The Spring conference of the Institute will be held at the Grand Hotel, Eastbourne, from May 20 to 22, and the annual conference at the Midland Hotel, Manchester, from October 6 to 8.

## Swedish Abstracts

**Fluxes for Aluminium.** Mr. T. Malmberg and Mr. G. Coyet, writing in *Gjuteriet* on "Fluxes for Melting Aluminium Alloys," have summarized their findings in the following statement:—

Different methods for comparing the effectivity of various fluxes have been tested. Methods based on the evolution of gas from cast samples or on microscopic estimation of the oxide content in polished samples have not given satisfactory results. Determining the metal recovery on the other hand seems to give reliable results. Laboratory tests showed that metal recovery when using flux containing sodium and potassium chloride and cryolite was at least equal to that obtained when using flux of a more complex composition. Foundry tests have confirmed that simple fluxes give high metal recovery, *i.e.*, small metal losses when melting charges with high or low oxide content. The main object of the flux is to separate the dross from the metal. In comparison with this the solubility of oxides in the flux seems to be of secondary importance.

**Rationalizing Foundrywork.** The June issue of *Gjuteriet* carries an article by Mr. C. G. Söderlund on "Rationalizing without Large Capital Investment." His summary states that almost all costs can be favourably influenced. Among the factors that can help in reducing costs he discusses in detail the effectivity of the organization, production control and method studies. Rational management of the melting department is discussed briefly and detailed data are given of the significance of the degree of mechanization for production per hour and for cost of production in the author's foundry. A change from hand moulding to machine moulding reduced the costs by 32 per cent. and with a roller conveyor a further 12 per cent. was gained.

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WM. DOXFORD & SONS, LIMITED—Mr. Arthur Storey has been elected a director.

# Refractory Materials for the Vitreous-enamelling Industry*

*By R. J. Slawson and J. F. Clements*

*The refractories industry is one of that group of important industries on which the manufacture of so many essential products depends. Refractory materials are almost entirely consumed by other industries. For this reason, the refractories industry is often unnoticed by the general public and, in the past, its products have tended to be taken for granted by the industries served.*

*It is sometimes surprising to consider to what extent industry is dependent on certain essentials. How many factories could maintain production without, for instance, insulated wire? In no direction are the conclusions likely to be more striking than the consideration of the dependence of industry on refractory materials. In almost every industrial process, refractories are a vital link in the chain from raw materials to finished product.*

*In this Paper it is proposed to consider the ways in which refractories are used by the vitreous-enamelling industry, to examine the desirable properties required for each use and then by a consideration of the properties of the various refractory materials available, to suggest suitable types for each purpose. It must, however, be realized that, in practice, cost and availability may over-ride other considerations.*

The information regarding the behaviour of various materials in use is largely obtained from industries other. than vitreous enamelling in the course of investigations carried out by the British Ceramic Research Association. Statements in this Paper therefore, which are based on that information, may not apply without qualification to the use of refractories under the particular conditions of the enamelling industry.

The discussion will be limited to a consideration of the use of refractories in frit-making furnaces and fusing furnaces. Space does not allow a consideration of boiler refractories, refractories for gas producers or the like, which, though they may be of interest to some enamellers, are not directly connected with the production or firing of enamels.

## FRIT-MAKING FURNACES

Frit-making furnaces may be divided into two general types: the rotary and the stationary or box type. Although other types for continuous melting, for instance, do exist, their problems, as far as refractories are concerned, should be covered by a consideration of these basic types.

In the rotary furnace, the whole of the refractory lining is exposed to the action of the molten frit. It must all, therefore, be constructed of material which is as resistant as possible to the corrosive action of the frit, or, rather, more particularly to the corrosive action of the molten alkalis and borax during the early stages of melting During the later stages of melting, when the furnace body is rotating, the action is rather that of erosion than corrosion. The erosive effect is often particularly marked on the mouth block, where it is concentrated during the operation of pouring.

When the charge is introduced into the hot furnace, there is a very sudden chilling of the lining and, unless the bricks are reasonably resistant to thermal shock they will spall, and flakes of the brick surface will be introduced into the frit. Even with the most suitable of refractories, this introduction of small pieces of brick is always likely to occur and it is therefore important that they should have as little deleterious effect on the enamel as possible. If the bricks contain little colouring oxide, particularly iron, small pieces entering the enamel are relatively harmless, but if the iron content is high then brown specks are likely to be formed in light-coloured enamels.

### Brick Shapes

It is usual to construct the lining of the kiln with arch bricks, using special shapes only for the ends and for the mouth block. This method of construction results in a great many joints and it is particularly at joints where attack by corrosion and especially by erosion causes the greatest damage. Often, also, the taper of the arch brick is not quite accurate for the diameter of the furnace and joints are formed which are either wide to start with or which widen as the surface of the brick is worn away, depending whether the taper was too great or too small in the first place. In either case, wear is more rapid than if the joint is uniformly thin throughout its depth. It is possible that increased life of linings could be obtained if, instead of bricks, specially-shaped larger blocks were used for the construction of the whole of the lining, thus reducing the number of joints and (if the blocks were made with sufficient accuracy) their thickness. Nevertheless, it is doubtful if such a scheme could be economically justified. In certain cases, however, it has been found worth while to increase the size of the mouth block so that a greater thickness has to be eroded away before a joint is reached (Fig. 1).

The required properties for the lining of a rotary furnace are therefore; high resistance to thermal

* Paper presented to the Institute of Vitreous Enamellers, the Authors are attached to the British Ceramic Research Association.

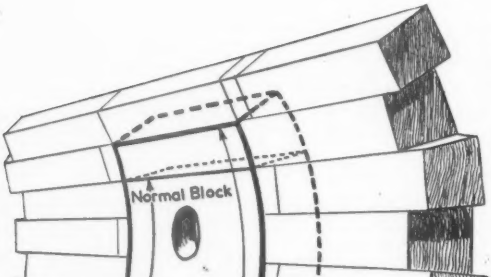



FIG. 1.—*Sketch showing use of Extended Mouth Block in a Rotary Melting Furnace*

shock, high resistance to corrosion and particularly high resistance to erosion. The iron content (or other colouring oxide) should be low if the furnace is to be used for white-enamel frits and, as with any refractory, the mechanical strength must be adequate for the purpose for which the bricks are used. A high degree of refractoriness, however, is not particularly necessary, for the temperatures involved are comparatively low.

### Stationary Kilns

In stationary frit kilns, rather different conditions obtain and the required properties may differ somewhat from those considered above. If the kiln is coal fired there must be some form of fire-box. It is not pertinent here to discuss the various forms of firebox which may be used, but it is sufficient merely to point out that it must have a refractory lining.

This lining must be sufficiently refractory to withstand the temperature involved, which may be considerably higher than that in the actual melting chamber. It must also be able to withstand the slagging action of coal ash. In the melting chamber itself, much the same conditions apply to the floor and the lower parts of the walls as were considered under the rotary furnace. In this case, however, corrosion is generally more important than erosion as the melting time is usually somewhat longer and there is less tendency for erosive effects to be concentrated near the tapping hole. The portion of the walls near the surface of the melted frit suffers the most serious attack and is generally known as the "flux line." There are at least two possible reasons why the attack is so marked in this position; in the first place it is at this point where the highest temperature of a frit/refractory interface occurs and, second, any erosive effect caused by convection currents will be concentrated here. It might therefore be an advantage to construct this part of the furnace with a refractory having a higher corrosion resistance even though the extra expense may be considerable. The upper parts of the walls and the roof of the furnace need to withstand high temperatures, as they receive the full heating effect of the flames and, as the charge receives its heat by radiation, it is desirable that they should be run as hot as is reasonably possible. Although there is some attack on the refractories by volatile matter from the frit and from certain products of combustion, it cannot be said that corrosion is a serious difficulty in the upper parts of the kiln.

In the rotary kiln, little can be done to conserve heat (apart perhaps from choosing, *ceteris paribus*, a refractory lining material with as low a thermal conductivity as possible), but in the stationary kiln both insulation and some form of heat recovery can be applied. Obviously, the desirable property of any insulator is as low a thermal conductivity as possible combined with the ability to withstand the temperature involved. It may be mentioned in this connection that insulation, although it will save heat, is not always an unmixed blessing on all parts of the kiln. On the flux line, for instance, the provision of insulation, by tending to increase the working temperature, will tend also to increase the rate of corrosion.

### Waste-heat Recovery

There are three main methods of recovery of what would otherwise be waste heat: the provision of flues in the side walls and floor of the kiln so that the sensible heat in the waste gases is used to heat the kiln structure, the use of a recuperator system to preheat the air or, lastly, a full regenerator system. In the case of kilns being used for the production of frits which evolve large amounts of volatile matter, or where the carry-over of fine material during charging is likely to occur, then the use of flues in the kiln structure is likely to be dangerous on account of blockages. As the kilns are relatively small it is unlikely that any elaborate system of heat recovery would be economically justified, but some simple form of recuperation may well be used. The incoming air, for instance, may be passed through flues in the walls or roof. Refractories for the construction of such air ducts must be reasonably impervious to gas at the pressure involved, so that the introduction of waste gas into the incoming air is avoided. A minor point in this connection is that the thermal conductivity of such refractories need not be low as heat passing through is not wasted but is returned to the furnace by the air. If a separate recuperator be used, the thermal conductivity should, of course, be as high as possible.

## FUSING FURNACES

There are a number of different types of enamel-fusing furnace—from the coal-fired box muffle to the continuous electric furnace—but the problems as far as refractories are concerned are similar in all. As the temperatures are not particularly high,

the selection of adequate refractory materials is not difficult and it is true to say that, generally, improvements in furnace design have tended to simplify the refractory problem still further. Thus, for instance, the introduction of electric heating or radiant-tube heating removes all the problems associated with the provision of an adequate muffle.

This discussion will therefore be confined to a consideration of the problems of the box-type muffle. In a coal-fired muffle there must be, of course, some type of fire-box. Here, as in the frit kiln, refractories resistant to the action of coal ash must be provided, but, as the temperature is lower, this is not so serious a problem. In an oil-fired furnace, where the combustion chamber is somewhat restricted in size, care must be taken that the refractories lining the chamber are capable of withstanding the rather higher flame temperature and the slagging action produced by some types of oil. The construction of the main part of the furnace is largely a problem of providing adequate insulation without too much bulk, though the size must not be reduced so far as to decrease the heat capacity and so increase the "come-back" time.

### Muffle Requirements

The most important consideration in a furnace of this type is the provision of a suitable muffle. Here it is essential that the heat transfer through the walls should be as efficient as possible. This may be achieved by the use of materials of high thermal conductivity and also by using as thin a layer of the material as its mechanical strength will allow. It is also essential that the muffle should be impermeable to the products of combustion or that the furnace design is such that the pressure in the muffle is higher than that outside. Generally, it seems to be safest to use a muffle as impermeable as possible and to operate it at a slight positive pressure. In the conditions applying during the fusing process, the thermal shocks to which the muffle is subjected are quite severe and an adequate shock resistance is very desirable. The question of heat recovery is similar in this case to that of the continuous frit kiln, but as the temperature is lower it may be even more difficult to justify any elaborate methods.

That concludes a very brief survey of the uses of refractories in the enamelling industry and the desirable properties associated with each use. These properties are shown in Table I.

## PROPERTIES AND TESTING

Having considered the ideal combinations of properties desirable in refractory materials intended for the enamelling industry, it is next proposed to discuss the properties of refractories in general and to describe briefly some of the methods of testing. It should be pointed out at this stage that many of these properties are interdependent and therefore some of the desirable combinations of properties may not be attainable in practice.

### General Properties

Apart from the intrinsic properties of the various materials, there are one or two properties of the particularly manufactured product which should be considered in choosing a suitable refractory material:—

(*a*) *Accuracy* in shape, particularly of special pieces, is always important in order to reduce the thickness of joints. It is not easy to produce high accuracy in the normal way, but in certain cases it is well worthwhile to use blocks which have been ground to shape after firing.

(*b*) *Dimensional stability* in use is extremely important, both in avoiding widening of joints and increased corrosion and in avoiding leakages in muffles. A test on sample pieces of the actual consignment should be carried out to determine if there is any change in size after refiring at a temperature somewhat higher than will be encountered in use. The temperature at which the re-firing is to be carried out and the tolerance allowable will depend on the particular use intended. Any serious change in size is generally an indication that the material has not been fired sufficiently well in the first place and is a good reason for rejection of the material.

TABLE I.—*Desirable Properties of Refractory Materials (see Key below).*

| | Refractoriness. | Thermal shock resistance. | Thermal conductivity. | Corrosion resistance. | Erosion resistance. | Mechanical strength. | Iron content. | Permeability. | Resistance to products of combustion (slagging). |
|---|---|---|---|---|---|---|---|---|---|
| *Rotary Furnace:* | | | | | | | | | |
| Lining | 3 | 1 | C | 1 | 2 | — | A | — | — |
| Mouth block | 3 | 1 | C | 1 | 1 | 2 | A | — | — |
| *Stationary Furnace:* | | | | | | | | | |
| Bottom and lower walls | 3 | 1 | — | 2 | 2 | 2 | A | — | — |
| Flux line | 2 | 3 | — | 1 | 2 | — | A | — | — |
| Upper walls and roof | 2 | 3 | — | 3 | — | 2 | — | — | — |
| Firebox | 2 | — | — | — | — | — | — | — | 1 |
| Flue | 3 | — | 3* | — | — | 3 | — | B | 2 |
| Recuperator (if used) | 2 | — | 2–1 | — | — | 2 | — | A | 2 |
| Insulation | — | — | A | — | — | — | — | — | — |
| *Fusing Furnace:* | | | | | | | | | |
| Firebox | 2 | — | — | — | — | — | — | — | 1 |
| Combustion chamber | 1 or 2 | — | — | — | — | 3 | — | — | 1 |
| Insulation | — | — | A | — | — | — | — | — | — |
| Muffle | 2 | 1 | 1 | — | — | 1 | — | A | 3 |

*Key*:—1—As high as possible; 2—high; 3—fairly high. A—As low as possible; B—low; C—fairly low; others —, not particularly important. * Applies only if flues are used for heat exchange.

(*c*) *Uniformity* of texture may be examined by breaking one or two pieces, when the exposure of any serious laminations or blowholes would be a reason for rejection.

### Physical Properties

Although it is possible to measure the physical properties of specimens of refractory materials to a high degree of precision, it is extremely difficult to relate these properties to the behaviour of the material in use. For this reason, simulative use tests, although not particularly accurate and generally incapable of giving absolute values, are often most useful in assessing the wearing properties. In this connection it is usual to devise some form of test specially for each intended use, and unless this is done it may be dangerous to draw conclusions from any test in which the conditions are widely different from those encountered.

(*a*) *Refractoriness*—or the ability of the material to withstand high temperatures—is generally expressed as a pyrometric cone number and is measured by comparing the softening point of the material with that of a standard series of pyrometric cones. (See Fig. 2.) Refractoriness as such is not of primary importance in the present connection, since most fireclays and other alumino-silicate materials are sufficiently refractory to withstand the temperatures involved in any of the vitreous-enamelling processes. The measurement of refractoriness is, however, often of value as a first indication of quality.

(*b*) *Thermal shock resistance* or the ability of the material to withstand sudden changes of temperature is not a single property but is a combination of a number of properties. It is improved by high mechanical strength and high thermal conductivity and by low thermal expansion and low modulus of elasticity. Unfortunately, some of these desirable properties are mutually exclusive and it is rare, for instance, to find high strength and low elasticity together.

Generally speaking, " hard " firing of the material, which is desirable for most other properties, tends to reduce the resistance to thermal shock, but this may often be offset during manufacture by a suitable grading of the raw materials.

There can, obviously, be no absolute test for thermal shock resistance, but it may be assessed by a simulative test in which the material, represented either by a set of small specimens or by a panel of brickwork, is exposed to a series of standardized temperature cycles. The shock resistance is then expressed as the number of such cycles required to cause failure. The definition of failure is arbitrary and depends on the type of test employed.

(*c*) *Thermal conductivity*. Materials of high thermal conductivity are of importance in the construction of muffle linings, while low-conductivity materials are essential for good insulation. In other situations, refractory materials will normally be selected on bases of other properties, but conductivity may be considered in the selection of, for instance, rotary-kiln linings, where, other properties being equal, a low conductivity would be an advantage. Generally speaking, properties which favour resistance to corrosion and erosion, such as low porosity and dense structure developed by high firing temperatures are accompanied by high conductivity. This is true whatever the composition of the material. The measurement of the thermal conductivity of refractory materials needs highly-specialized apparatus (Fig. 3), in which the amount of heat passing through a panel of the material under a known temperature gradient is measured in a calorimeter, but rough comparison tests may be made by placing similar-size blocks of the material on a hot plate and measuring the temperature of their upper faces.

### Chemical Properties

As far as the enamelling industry is concerned, the most serious problem in refractory materials is the question of corrosion by molten frit in the melting furnace. Although not entirely a chemical property it is most markedly influenced by the chemical composition of the material. Of recent years, the problem has become even more acute, owing to the tendency to use enamel frits of lower viscosity and to increase production by working at a somewhat higher temperature. The whole mechanism of corrosion and erosion is extremely complicated and it is very difficult to separate the effects of various factors.

Probably the most important point to be considered is the viscosity of the products of reaction. There is no refractory material (except perhaps platinum) which is not attacked by molten material such as an enamel frit. The damage caused by the reaction and the rate of the reaction itself will depend on the viscosity of the product, and any

FIG. 2.—*Refractoriness Test. Specimens Before (left) and After Firing. The Test Sample is in the centre of the Ring of Standard Cones.*

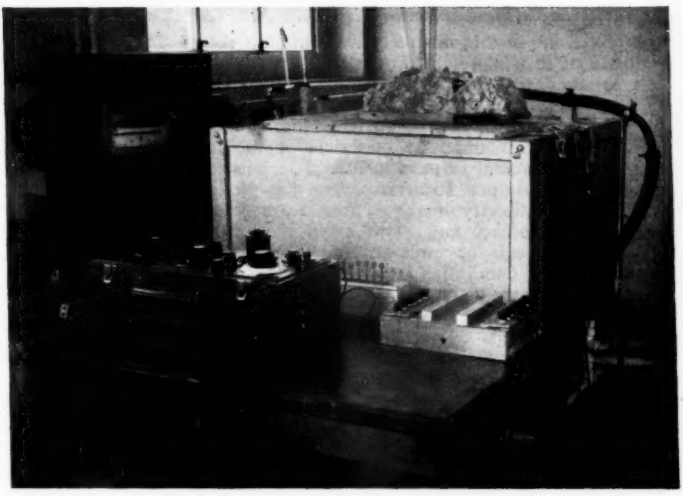


FIG. 3.—*Aparatus for the Determination of Thermal Conductivity of Refractories.*

method by which this viscosity can be increased will tend to increase the life of the refractory material. The content of alkalis, lime and magnesia, in the refractory should be kept to an absolute minimum, and, providing other properties are not adversely affected, the content of alumina should be as high as possible. Another way in which the viscosity of the reaction products may be increased is to reduce the temperature at the point where corrosion is most severe. On the flux line of a stationary furnace, for instance, insulation may be removed and the blocks may be cooled by an air blast.

### Corrosion Resistance

Resistance to corrosion also depends to a lesser degree on the texture of the material. Fine texture and low porosity will assist resistance to corrosion at a given composition, and it is generally agreed that at a given porosity it is better to have a large number of small pores than a small number of larger ones, as this type of texture is more effective in confining the attack to the surface. In the case of erosion resistance, however, the relative importance of composition and texture is reversed and the latter is the more important. Many bricks which produce a viscous reaction product and are consequently corrosion resistant, consist of resistant grains in a relatively soft matrix. Erosive action removes the viscous reaction product as fast as it forms and the soft matrix is left continually open to attack. This form of attack is noticeable in firebricks containing a "hard-fired" grog in a clay bond, which has been "easy" fired. Similarly, the effect is seen in sillimanite materials which have not been fired sufficiently well. Hard-firing, therefore, as well as increasing the resistance of materials to corrosion is even more beneficial in its effect on erosion resistance.

This effect of texture often complicates attempts to assess the value of certain constituents in increasing corrosion resistance as, for instance, in the case of alumina. It has been claimed that, while firebricks containing about 20 per cent. alumina and sillimanite materials containing about 60 per cent. alumina are resistant to corrosion, intermediate alumina contents of 30 to 40 per cent. alumina are prone to attack. It is known that these intermediate compositions are often more porous than either of the others, and this is probably the reason for the curious result. It is probably true to say that of two materials of similar texture and porosity, the one with the higher alumina content will be the more resistant to attack, and, similarly, if the alumina contents are equal then the brick with the finer texture and lower porosity will have the advantage.

### Zircon Refractories

It has been claimed that refractory materials based on zircon have very high resistance to corrosion and erosion, but as yet there seems to be little reliable evidence. The viscosity of many zircon-containing materials is certainly high, and they may therefore prove their value. On the other hand, it should be emphasized that unless the bonding material in the brick is resistant, the erosion resistance will not be increased. With any of the special types of refractory material, it is essential that they should be fired as "hard" as possible and that the special materials (sillimanite or zircon) should not be treated merely as a substitute for fireclay grog. Bricks containing such highly-refractory materials may be fired at considerably higher temperatures than ordinary firebricks and unless this is done there is not likely to be much improvement in resistance to erosion.

It is practically impossible to give more than a very rough estimate of the corrosion resistance of a material merely by a consideration of its composition and physical properties. The only way of assessing this resistance is by carrying out tests with the actual brick and corrosive agent involved. The frit or slag may be formed into a cylindrical pellet and melted on a piece of the refractory material (Fig. 4), or a larger quantity may be melted in a crucible made from the same material. In either case, the test is simply one of comparison and the degree of attack is assessed by a visual examination of a section cut through the test-piece.

The simultaneous effect of corrosion and erosion may be simulated by suspending pieces of the refractory material in a bath of molten frit or slag where they are exposed to convection currents in the liquid. In addition to visual examination of

sections, it is possible in this test to obtain a rough estimate of loss in weight, but it is extremely difficult to standardize conditions with sufficient accuracy in a test of this kind. By far the most satisfactory method of comparing the probable working lives of different materials is to build them into the actual furnace in use. It is generally possible, for instance, to arrange that the flux-line bricks in a stationary melting furnace are reasonably easy to replace and various types of refractory material can be built in and tested under actual working conditions.

## PROPERTIES OF REFRACTORIES

In this section, the properties of some types of refractory materials which may be of interest in the enamelling industry will be discussed.

### Fireclay Refractories

Fireclay products are the commonest and cheapest refractory materials. Being made from a variety of fireclays there are numerous qualities and grades available. From the various types on the market, it is usually possible to find one to perform, with a reasonable degree of success, any of the functions required in the enamelling industry. Low-grade fireclays given an "easy" fire are fairly satisfactory insulators, fireclay of high-alumina content and well fired has a reasonably good corrosion resistance and, as it has good mechanical strength and reasonably high conductivity, may be made into specially-thin shapes for use in muffle linings. Manufacturers are generally able to recommend suitable grades for each specific purpose.

### Silica and Siliceous Refractories

It seems unlikely that there is any considerable application of silica brick in the enamelling industry. It is highly refractory, has a low iron content and its resistance to alkaline attack is quite high but its high porosity and extreme sensitivity to thermal shock makes it unsuitable for most of the purposes under discussion. It might be used for the crown of a continuous frit-kiln, or in similar situations where it would be required to withstand continuous and unvarying high temperature.

### Sillimanite Refractories

The average composition of the so-called sillimanite refractories is about 20 per cent. clay bond and 80 per cent. calcined kyanite, giving a final composition which contains about 60 per cent. alumina and 40 per cent. silica. Refractory materials made with different proportions of bond are available for special purposes. The minerals kyanite, andalusite and sillimanite are all of the same chemical composition ($Al_2O_3.SiO_2$) though of differing crystalline form. They all decompose at high temperature to give mullite ($3Al_2O_3.2SiO_2$) and free silica. It is generally considered that it is the mullite content which confers the valuable properties on these materials. Either of the three minerals mentioned can be used, but nowadays, for economic reasons, kyanite is employed exclusively in this country.

The sillimanite refractories are somewhat similar in their properties to fireclay, but they are notably superior in their resistance to corrosion and erosion by molten frits and glasses. This resistance, however, is not fully developed unless the material has received the "extra-hard" fire in manufacture, compared with that given to fireclay, which it will withstand without distortion. Sillimanite refractories which have received only the same fire as ordinary firebrick will have very little, if any, greater resistance to corrosion. Providing therefore that they have been adequately fired, sillimanite materials are often of value in frit-making furnaces. Their resistance to iron-bearing slags, however, is not high and for the lining of fireboxes and combustion chambers they have no advantage over the firebrick. There is some evidence to suggest that this remark may apply to their resistance to some of the extremely corrosive ground-coat frits now being used in the industry. Sillimanite refractories are very considerably more expensive than fireclay and, at present the supply position is very uncertain.

### Fused Alumina

Fused alumina grog may be bonded with small amounts of clay and fired to produce a refractory material having a high thermal conductivity. This is well suited to the production of muffle linings.

### Silicon Carbide

Silicon-carbide grog may also be used to produce a muffle-lining material of very high conductivity. Unfortunately, silicon carbide is liable to oxidation at the temperatures used in enamelling muffles and many early attempts to use this material failed. Now, however, it is claimed that this difficulty has been overcome by coating the refractory with an impermeable layer, but little evidence seems to be available of the efficacy of this method.

FIG. 4.—*"Pill Test" Specimens Before and After Firing.*

### Insulating Bricks

There are several different types of insulating bricks available but they may all be classed into two main groups:—

TABLE II.—*Properties of Various Types of Refractory Materials.*

| | Fireclay products. | Silica brick. | Sillimanite products. | Fused alumina. | Silicon carbide. | High-temp. insulation. | Medium-temp. insulation. |
|---|---|---|---|---|---|---|---|
| Refractoriness { Cone No. .. | 27 to 34 | 31 to 33 | 36 to 38 | >38 | >38 | — | — |
| Refractoriness { Deg. C. .. | 1,610 to 1,750 | 1,690 to 1,730 | 1,790 to 1,850 | >1,850 | >1,850 | — | — |
| Thermal shock resistance (cycles to cause failure) | 20 to 30+ | 1 to 3 | 30+ | 30+ | 30+ | 5 to 20 | 20 to 30 |
| Thermal conductivity (B.T.U./ft.²/hr./deg. F./in.) | 8 to 11 | 8 to 12 | 8 to 12 | 21 to 25 | 100 to 170 | 2 to 3 | 0.8 to 1.2 |
| Cold crushing strength (lb. per sq. in.[5]) | 2,000 to 5,000 | 3,000 to 5,000 | 2,000 to 6,000 | — | 2,500 to 5,000 | 200 to 800 | 150 to 200 |
| Iron content (per cent. $Fe_2O_3$) | 2 to 6 | 0.4 to 1.4 | 0.5 to 2.0 | 1 | 0.2 to 0.5 | 1.2 to 5.0 | 2 to 5 |
| Permeability (c.g.s. units) .. | 0.01 to 0.1 | 0.05 to 0.6 | 0.02 to 0.1 | 0.02 to 0.05 | 0.02 to 0.2 | 0.4 to 1.5 | 0.002 to 0.05 |
| Porosity (per cent.) .. .. | 15 to 30 | 20 to 32 | 15 to 32 | 20 to 26 | 15 to 28 | 65 to 80 | 65 to 75 |
| Bulk density (gm. per cub. cm.) | 1.8 to 2.2 | 1.6 to 1.9 | 2.05 to 2.55 | 2.85 to 3.1 | 2.2 to 2.5 | 0.5 to 1.0 | 0.5 to 0.8 |
| Weight of standard square (lb.) | 8 to 10 | 7 to 8½ | 9 to 11 | 12½ to 13½ | 10 to 11 | 2 to 4 | 2 to 3½ |

(1) Medium-temperature bricks of very low thermal conductivity, but resistant only to temperatures of less than about 900 deg. C. These bricks are used as backing insulation outside a layer of some other type of refractory. They are generally made from diatomaceous earth.

(2) High-temperature insulating bricks of fairly low thermal conductivity and sufficient temperature resistance to be used for the walls and arches of muffle kilns and the internal structure of electric kilns. They are not suitable for use in situations where they are likely to come into contact with molten slag or frit. Most of these bricks are made from refractory clays and owe their insulating properties to their high porosity.

Owing to their relatively low mechanical strength, insulating bricks should not be relied on to support any considerable load. Table II shows the ranges of properties which may be encountered in the various refractory materials considered. As has already been stated, fireclay refractories may be used with reasonable satisfaction for almost all purposes in the enamelling industry but it is not suggested that fireclay is necessarily the best material for each purpose. It is certainly the cheapest and before substituting any of the more expensive materials a very careful consideration of costs is necessary. This costing must be based largely on simulative tests and if possible on full-scale trials. Without such trials it is quite impossible to estimate whether the substitution of sillimanite, for instance, in certain parts of a frit kiln would be economically justified. The position is further complicated by the difference in the corrosive power of different frits and even if the substitution of the more expensive material could be justified in a kiln making one type of frit there is no guarantee that it would be equally justified in another.

## RECOMMENDATIONS

In returning to the original list of desirable properties and trying, from the given properties of the materials, to see what recommendations can reasonably be made, it must be stressed again that economic consideration will generally be the deciding factor.

### Rotary Furnace

*Lining.*—In most cases it is fairly certain that sillimanite linings would last longer than the normal fireclay. They would however be more costly and, unless properly fired, the increase in life would not be likely to be great.

*Mouth Block.*—When producing frits which cause the mouth block to be worn away long before the rest of the lining is worn out, then the substitution of sillimanite is generally worth while, as also is the modification in shape already mentioned.

### Stationary Melting Furnace

*Firebox.*—Hard-fired firebricks are the most suitable material.

*Bottom and lower walls.*—Here much the same consideration applies as to the lining of the rotary furnace.

*Flux line.*—With many frits, the use of sillimanite will very probably increase the life considerably, but with some of the more corrosive frits, there seems to be little difference between any of the available materials. In these cases, the only solution seems to be to cool the flux line and to construct the furnace in such a way that the flux-line blocks can be replaced without complete rebuilding.

There have been reports from time to time that zircon refractories are found to be satisfactory in American practice, but that the expense is very high.

*Upper walls and roof.*—Fireclay is certainly the most satisfactory material for these positions. Unless very special precautions are taken, silica is too sensitive to heat shock and high-temperature insulating bricks are not sufficiently resistant to the slagging action of frit vapour.

*Flues.*—In flues there is an obvious choice between firebrick and high-temperature insulating brick and the final selection will depend on various factors. In the waste-gas flues, insulating brick should not be used where it is likely to be slagged by volatile matter or mechanically-carried batch material, but it is quite satisfactory in cooler positions. In flues used for preheating air, the high permeability and low thermal conductivity of insulating bricks would be a disadvantage and well-fired fireclay would be the most suitable material.

*Recuperator.*—If a separate recuperator is used, then, obviously, the highest possible thermal conductivity is desirable and fused-alumina or silicon-carbide tubes are indicated.

*Insulation.*—Where insulation is applied, the choice lies between the high-temperature and medium-temperature types and will depend on the

*Refractories for the Enamelling Industry*

temperature conditions to which the material is to be exposed. In addition to the use of insulating bricks, expanded vermiculite in granular form is finding extended employment for the insulation of furnace crowns.

### Fusing Furnaces

*Firebox.*—See under stationary melting furnace.

*Combustion chamber and flues.*—Generally, firebrick or high-temperature insulating brick may be used. The choice will often depend mainly on the load to be carried.

*Insulation.*—An outer casing of medium-temperature insulating bricks is very effective in reducing avoidable heat loss.

*Muffle.*—Hard-fired clay, particularly when made into special shapes to give high mechanical strength without excessive wall thickness, is satisfactory but heat transmission is more efficient with fused alumina or particularly with silicon carbide.

### Conclusion

In a very general statement it may, therefore, be concluded that the refractory problems of the enamelling industry are relatively simple, except for the problem of corrosion, and that the position in regard to the latter may be fairly stated as follows: A good fireclay product resists corrosion fairly well —there are other materials which are or may be more resistant but they are considerably more expensive. It must be remembered, however, that all fireclay products are not equally satisfactory for all purposes and the properties of any particular brand or quality should be determined and compared with the ideal properties required for the particular purpose intended. In most cases, of course, the manufacturer will be in a position to recommend the most suitable grade, providing he is given full information about the intended use.

### Acknowledgments

The Authors wish to thank the director of research, Dr. A. T. Green, O.B.E., of the British Ceramic Research Association for permission to present this Paper. Thanks are extended also to Mr. H. Laithwaite of Radiation Limited, for information regarding recent trends in the enamelling industry.

## Draft Regulations, 1953

The *ad hoc* committee of the Council of Ironfoundry Associations, which was appointed to consider the draft Regulations for Iron and Steel Foundries met officials of the Factory Department of the Ministry of Labour and National Service early in May and submitted evidence in support of the objections and amendments to the regulations which had been made on behalf of member-firms. The Factory Department has now completed its consideration of the C.F.A.'s evidence and it is expected that a revised draft of the Regulations will be issued shortly.

The revision will embody some of the amendments proposed by the C.F.A. and copies will be sent to every member-firm for their comments as soon as it is published. The *ad hoc* committee will consider the revised draft and will, if necessary, lodge further objections.

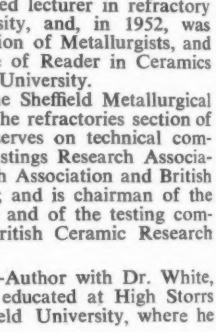
## Conference Paper Authors

DR. J. WHITE, one of the Authors of the Paper " Effect of Heat on Clays and its Bearing on the ' Life ' of Clay Bonds," which is printed in this issue, was born at Langholm, Dumfriesshire, and was educated at Langholm Academy, Dumfries Academy, and Glasgow University, where he graduated B.SC. with first-class honours in Physical Chemistry, in 1931. The same year he entered the Royal Technical College, Glasgow, with a research scholarship in metallurgy awarded by the Department of Scientific and Industrial Research and later became research assistant to Prof. R. Hay in the Metallurgy Department and then lecturer in metallurgy in the College. In 1934, he was awarded Associateship of the College in Metallurgy, and, in 1935, the degree of PH.D. of Glasgow University. In 1939, the Carnegie Gold Medal of the Iron and Steel Institute for Research was conferred on him and he graduated D.SC.(GLASGOW).

In 1943, he left Glasgow to become research technologist with General Refractories, Limited, at Worksop. In 1946, he was appointed lecturer in refractory materials at Sheffield University, and, in 1952, was elected a fellow of the Institution of Metallurgists, and in the same year had the title of Reader in Ceramics conferred on him by Sheffield University.

He is a past-president of the Sheffield Metallurgical Association; vice-president of the refractories section of the British Ceramic Society; serves on technical committees of the British Steel Castings Research Association, British Cast Iron Research Association and British Ceramic Research Association; and is chairman of the Joint Sand Testing Committee and of the testing committee (refractories) of the British Ceramic Research Association.

MR. S. DAVISON, who is co-Author with Dr. White, was born in Sheffield and educated at High Storrs Grammar School and Sheffield University, where he graduated B.SC.(TECH.) in glass technology, in 1943. After holding the post of research assistant in Glass Technology in the Department from 1943 to 1948, he left to become technical manager with a firm of refractory manufacturers. In 1950, he was awarded a research bursary by the Steel Castings Division of the British Iron and Steel Research Association tenable in the Refractories Department of Sheffield University for research on bonding clays. Responsibility for the support of this work later passed to the then British Steel Founders' Association (Research and Development Division), now the British Steel Castings Research Association. Mr. Davison has now completed this work and has been awarded the Frank Holland Memorial Prize of the University for it. He hopes to submit a thesis for the degree of PH.D. shortly.



# News in Brief

ADAMS HYDRAULICS, LIMITED, have prepared plans to raise the foundry roof at Peaseholme Green, York.

THE ENGLISH REGIONAL OFFICES of the Ministry of Supply and the Board of Trade are to be merged into one unit.

THE GROUP PROFITS of Sheepbridge Engineering, Limited, Chesterfield, in the year ended March 31, fell by £16,608 to £1,057,744, compared with £1,074,352 in the previous year.

THE SECOND NATIONAL FACTORY EQUIPMENT EXHIBITION will be held at the Royal Horticultural Society's Halls, Westminster, from March 22 to March 26, 1954.

MEMBERS of the British Productivity Council held a conference last week with the chairmen or representatives of 40 local productivity committees which have been formed recently or are in course of formation.

THE JULES SIEGFRIED TECHNICAL COLLEGE at Havre has opened a department devoted to the teaching of foundry practice, and for this purpose has equipped laboratories well suited for the purpose, especially as they will cater for local industries.

BIRMINGHAM CORPORATION has completed its contract with the Iron and Steel Federation to supply 6,000 tons of disused tramway tracks at £12 a ton. The price was agreed in January and the condition of delivery before September has been fulfilled.

THE AMALGAMATED ENGINEERING UNION has put down a resolution for the annual conference of the Confederation of Shipbuilding and Engineering Unions to be held this month, asking for the immediate introduction of a 40-hour week without loss of earnings.

OUTPUT RECENTLY from No. 10 blast furnace of the Appleby-Frodingham Steel Company (Branch of the United Steel Companies, Limited), Scunthorpe, of 5,600 tons of iron broke the weekly record, established in the previous week, by 380 tons.

A 60-TON ARC FURNACE is planned in the new electric-steel plant about to be erected at the Stocksbridge works, Sheffield, of Samuel Fox & Company, Limited, It is claimed to be the largest of its type in the country and it is expected that a weekly output of 1,000 tons will be produced.

CUXSON, GERRARD & COMPANY, LIMITED, Fountain Lane, Oldbury, Birmingham, announce that as from September 1, MR. W. J. EDWARDS, M.P.S., "Shangani," Ringswell Avenue, Exeter, will cover the firm's interests in the Channel Islands as well as Somerset, Devon, Cornwall, Dorset, and Wilts.

IN THE FIRST SIX MONTHS of this year 1,402,420 tons of foreign ore was discharged on Tees-side compared with 1,411,710 tons in the corresponding period of last year. In the same period arrivals of iron and steel scrap totalled 115,879 tons compared with 18,022 tons in the first six months of 1952.

THE AUSTRALIAN BRANCH (VICTORIA) of the Institute of British Foundrymen has been invited to visit the New South Wales Division of the Institute of Australian Foundrymen on September 1 and 2 to participate in a convention, in connection with which a Foundry Exhibition is to be staged.

THE SECOND INSTALMENT of the profit-sharing bonus of W. G. Allen & Sons (Tipton), Limited, was paid to some 400 workers before the holiday period last week. Generally, employees will have received between £20 and £30 this year under the scheme, which is based on a points system governed by length of service.

DALE ELECTRIC (YORKSHIRE), LIMITED, Electricity Building, Filey, E. Yorks, have designed and placed on the market a small mobile Diesel-engine-driven generating plant suitable for installing in home or workshops. The motive power is furnished by a 2½-h.p. single-cylinder, direct-injection type engine.

HARVEY & LONGSTAFFE, LIMITED, engineers' pattern-makers, non-ferrous and light-alloy founders, have now removed to Piercy Street, Ancoats, Manchester, 4. The new works and foundry are much larger than the original premises, the change having been necessitated by the increased volume of business.

A ONE-DAY CONVENTION on the subject of responsibilities and opportunities in engineering production will be held at Birmingham University on September 5, by the Institution of Production Engineers. Professor T. U. Mathew will open the convention and the summing up will be given by Sir Cecil Weir.

FIVE MASSIVE CRUSHERS have recently been installed by the International Nickel Company of Canada, Limited, at its Creighton and Frood-Stobie Mines in Northern Ontario as part of the company's underground mining expansion programme. Each of these powerful machines weighs 165 tons and crushes about 450 tons of ore an hour, reducing it to eight-inch pieces.

TO MEET THE INSISTENT DEMAND of steel and other industries on Tees-side for greater supplies of oil, a new oil installation is under construction by Whessoe, Limited, Darlington, for Shell-Mex & BP, Limited, at Teesport, Middlesbrough. Completion of the installation is expected by the end of next year, at a cost of £600,000.

THE PRODUCTIVITY GAP between Britain and America was being widened as America advanced far more rapidly, with new methods of production, Lord Bennett said last month, when he opened Birmingham University's new Institute for Engineering Production in Norfolk Road, Edgbaston. The Institute has been established with a £54,000 endowment from Joseph Lucas, Limited.

INSTITUTE OF PERSONNEL MANAGEMENT, in collaboration with the Personnel Management Branch of the Ministry of Labour, have organized a five-day residential study course on Employment and Welfare, to take place at the Coburg Court Hotel, Bayswater Road, London, W.2, from September 6 to 11. Details are available from the Institute at Management House, 8, Hill Street, London, W.1.

ORDERS totalling £1,071,000 have been placed with the Goodyear Tyre & Rubber Company, Wolverhampton, for wheels, brakes, spare parts and tyres, for American aircraft operating from Europe. Brakes will be of the single-disc type and will be made, together with the wheels at the Nesgoodyear Aviation Products factory at Wallasey. The tubes and tyres will be made in Wolverhampton.

BIRMINGHAM PUBLIC WORKS COMMITTEE proposes to convert Granville Ironworks, Ruston Street, Ladywood, to accommodate up to eight separate firms. The building is subject to a compulsory purchase order and the proposals are part of the Birmingham redevelopment plan for new multiple factory buildings to house small firms displaced from the central areas under development schemes.

HOWELL & COMPANY, LIMITED, Meadowhall, Sheffield, normally producing steel boiler tubes, have recently been co-operating with Herbert Morris, Limited, Loughborough, in manufacturing a 2¼-ton portable jib

(*Continued on page* 190)

# Imports and Exports of Iron and Steel in June

The following tables, based on Board of Trade returns, gives figures of imports and exports of iron and steel in June. Figures for the same month in 1952 are given for the purpose of comparison, and totals for the first four months of 1952 and 1953 are also included. (All figures in tons.)

*Total Exports of Iron and Steel by Destination*

| Destination. | Month ended June 30. | | Six months ended June 30. | |
|---|---|---|---|---|
| | 1952. | 1953. | 1952. | 1953. |
| Channel Islands | 550 | 411 | 3,709 | 3,224 |
| Gibraltar | 452 | 151 | 1,039 | 1,108 |
| Malta and Gozo | 218 | 262 | 1,269 | 1,825 |
| Cyprus | 734 | 863 | 2,963 | 6,625 |
| Sierra Leone | 572 | 1,781 | 2,777 | 4,739 |
| Gold Coast | 2,514 | 2,194 | 16,199 | 22,862 |
| Nigeria | 4,100 | 5,058 | 22,748 | 31,342 |
| Union of South Africa | 11,162 | 7,555 | 74,255 | 74,248 |
| Northern Rhodesia | 2,431 | 1,429 | 15,389 | 13,252 |
| Southern Rhodesia | 5,873 | 6,343 | 26,460 | 33,401 |
| Tanganyika | 2,113 | 942 | 11,518 | 9,491 |
| Kenya | 2,550 | 5,707 | 22,871 | 39,248 |
| Uganda | 457 | 2,412 | 3,702 | 5,687 |
| Mauritius | 580 | 740 | 3,048 | 4,658 |
| Bahrein, Qatar, and Trucial Oman | 1,039 | 2,509 | 8,635 | 16,066 |
| Kuwait | 1,454 | 1,411 | 9,078 | 15,423 |
| India | 6,887 | 4,679 | 37,790 | 37,544 |
| Pakistan | 4,803 | 2,657 | 37,780 | 18,674 |
| Malaya | 5,052 | 4,318 | 39,843 | 36,405 |
| Ceylon | 1,711 | 1,444 | 11,991 | 12,624 |
| North Borneo | 244 | 265 | 1,668 | 3,050 |
| Hongkong | 1,302 | 1,814 | 10,076 | 17,228 |
| Australia | 22,392 | 9,761 | 166,410 | 92,414 |
| New Zealand | 11,496 | 6,112 | 72,033 | 65,252 |
| Canada | 13,113 | 24,376 | 93,557 | 101,338 |
| Jamaica | 749 | 1,765 | 13,787 | 10,771 |
| Trinidad | 3,373 | 3,560 | 25,340 | 21,755 |
| British Guiana | 1,028 | 355 | 3,306 | 3,420 |
| Anglo-Egyptian Sudan | 2,042 | 2,281 | 9,742 | 15,105 |
| Other Commonwealth | 2,746 | 5,762 | 16,066 | 36,744 |
| Irish Republic | 5,957 | 4,545 | 33,913 | 28,264 |
| Soviet Union | 549 | — | 586 | 4 |
| Finland | 2,612 | 1,393 | 31,651 | 15,007 |
| Sweden | 7,891 | 4,628 | 60,037 | 39,892 |
| Norway | 4,053 | 5,764 | 31,788 | 33,893 |
| Iceland | 126 | 676 | 1,594 | 1,942 |
| Denmark | 5,200 | 8,663 | 45,550 | 48,188 |
| Poland | 5 | 19 | 86 | 213 |
| Western Germany | 162 | 138 | 767 | 5,612 |
| Netherlands | 8,524 | 10,478 | 49,689 | 73,267 |
| Belgium | 573 | 1,561 | 4,155 | 11,743 |
| France | 169 | 2,096 | 1,262 | 7,402 |
| Switzerland | 730 | 1,336 | 4,754 | 5,632 |
| Portugal | 473 | 2,108 | 4,605 | 9,865 |
| Spain | 1,431 | 242 | 4,639 | 2,796 |
| Italy | 367 | 3,285 | 6,839 | 24,901 |
| Austria | 27 | 135 | 319 | 747 |
| Yugoslavia | 316 | 676 | 2,762 | 2,183 |
| Greece | 247 | 155 | 1,961 | 1,934 |
| Turkey | 642 | 304 | 4,369 | 6,567 |
| Netherlands Antilles | 1,030 | 788 | 6,843 | 5,932 |
| Belgian Congo | 165 | 260 | 1,610 | 1,307 |
| Angola | 76 | 1,300 | 2,222 | 5,054 |
| Portuguese E. Africa | 413 | 150 | 2,625 | 1,933 |
| Canary Island | 35 | 19 | 457 | 341 |
| Syria | 445 | 446 | 1,455 | 1,121 |
| Lebanon | 201 | 283 | 7,549 | 3,630 |
| Israel | 1,060 | 923 | 8,781 | 4,238 |
| Egypt | 2,965 | 1,884 | 17,518 | 14,600 |
| Saudi Arabia | 709 | 393 | 3,406 | 1,756 |
| Iraq | 5,537 | 11,850 | 27,268 | 41,233 |
| Iran | 1,380 | 107 | 5,939 | 2,030 |
| Burma | 959 | 1,761 | 6,828 | 11,205 |
| Thailand | 946 | 545 | 4,782 | 6,298 |
| Indonesia | 1,224 | 1,250 | 8,314 | 8,313 |
| China | — | — | 8 | 159 |
| Philippine Republic | 16 | 429 | 2,174 | 1,802 |
| U.S.A. | 2,437 | 19,569 | 25,003 | 43,325 |
| Cuba | 220 | 156 | 1,253 | 2,174 |
| Colombia | 329 | 1,530 | 2,750 | 5,617 |
| Venezuela | 2,469 | 4,700 | 21,946 | 29,237 |
| Ecuador | 235 | 137 | 2,199 | 1,629 |
| Peru | 553 | 2,161 | 4,797 | 5,878 |
| Chile | 80 | 327 | 2,047 | 1,516 |
| Brazil | 1,736 | 255 | 13,453 | 1,841 |
| Uruguay | 171 | 346 | 3,068 | 886 |
| Argentina | 2,045 | 2,101 | 20,082 | 8,129 |
| Other foreign | 1,098 | 2,216 | 10,697 | 12,371 |
| TOTAL | 182,325 | 213,005 | 1,271,449 | 1,299,130 |

*Total Imports of Iron and Steel and Origin*

| From | Month ended June 30. | | Six months ended June 30. | |
|---|---|---|---|---|
| | 1952. | 1953. | 1952. | 1953. |
| India | 2 | 34 | 228 | 162 |
| Canada | 16,366 | 2,124 | 54,179 | 58,614 |
| Other Commonwealth countries and the Irish Republic | 195 | 16,018 | 2,309 | 60,736 |
| Sweden | 2,018 | 1,230 | 13,815 | 9,641 |
| Norway | 9,256 | 5,969 | 36,676 | 30,771 |
| Western Germany | 7,977 | 5,166 | 47,948 | 27,334 |
| Netherlands | 9,584 | 15,164 | 67,416 | 68,211 |
| Belgium | 27,871 | 20,090 | 152,892 | 131,447 |
| Luxembourg | 16,599 | 10,732 | 81,515 | 69,219 |
| France | 19,934 | 18,075 | 122,427 | 155,045 |
| Italy | 4,253 | — | 7,098 | 12,812 |
| Austria | 24,873 | 52,293 | 73,146 | 227,788 |
| Japan | 22,216 | 1,098 | 79,696 | 56,210 |
| U.S.A. | 87,684 | 3,462 | 333,896 | 99,765 |
| Other foreign countries | 550 | 3,362 | 3,389 | 29,788 |
| TOTAL | 249,378 | 154,817 | 1,076,630 | 1,037,543 |
| Iron and steel scrap and waste, fit only for the recovery of metal | 71,947 | 108,124 | 280,375 | 420,828 |

*Exports of Iron and Steel by Product*

| Product. | Month ended June 30. | | Six months ended June 30. | |
|---|---|---|---|---|
| | 1952. | 1953. | 1952. | 1953. |
| Pig-iron | 419 | 455 | 2,052 | 2,974 |
| Ferro-tungsten | 11 | 4 | 87 | 28 |
| Other ferro-alloys | 206 | 113 | 1,910 | 1,254 |
| Ingots, blooms, billets, and slabs | 2 | 92 | 158 | 306 |
| Iron bars and rods | 299 | 130 | 1,949 | 1,091 |
| Wire rods | 57 | 1,879 | 610 | 7,078 |
| Bright steel bars | 1,251 | 1,162 | 6,598 | 8,334 |
| Alloy steel bars and rods | 1,312 | 1,330 | 7,834 | 8,510 |
| Other steel bars and rods | 8,985 | 5,958 | 57,621 | 51,077 |
| Angles, shapes, and sections | 10,538 | 8,062 | 69,522 | 60,968 |
| Iron and other castings and forgings | 767 | 1,965 | 6,494 | 7,836 |
| Girders, beams, joists, and pillars (rolled) | 1,881 | 1,123 | 18,429 | 11,152 |
| Hoop and strip | 3,212 | 7,408 | 25,592 | 30,765 |
| Iron plates and sheets | 6 | 44 | 229 | 215 |
| Tinplate | 21,867 | 15,813 | 151,161 | 131,307 |
| Tinned sheets | 237 | 269 | 903 | 860 |
| Terneplates and decorated tinplates | 52 | 84 | 392 | 614 |
| Other steel plate (⅛ in. thick and over) | 14,491 | 20,878 | 120,091 | 119,804 |
| Galvanized sheets | 5,239 | 8,822 | 32,810 | 50,676 |
| Black sheets | 8,686 | 27,627 | 69,136 | 89,548 |
| Other coated plates and sheets | 915 | 614 | 5,364 | 5,134 |
| Cast-iron pipes up to 6 in. dia. | 6,960 | 7,173 | 45,419 | 41,986 |
| Do., over 6 in. dia. | 5,800 | 5,272 | 33,154 | 35,245 |
| Wrought-iron tubes | 32,191 | 35,405 | 217,876 | 221,789 |
| Railway material | 15,521 | 19,191 | 101,645 | 127,405 |
| Wire | 3,463 | 4,057 | 26,995 | 28,165 |
| Cable and rope | 2,146 | 2,104 | 15,408 | 16,428 |
| Wire nails, etc. | 1,083 | 1,598 | 8,271 | 9,557 |
| Other nails, tacks, etc. | 361 | 587 | 3,376 | 2,391 |
| Rivets and washers | 498 | 302 | 3,222 | 2,385 |
| Wood screws | 286 | 94 | 2,148 | 1,031 |
| Bolts, nuts, and metal screws | 1,509 | 1,611 | 12,875 | 10,099 |
| Baths | 666 | 337 | 8,825 | 2,012 |
| Anchors | 743 | 556 | 5,299 | 5,142 |
| Chains, etc. | 642 | 681 | 5,271 | 4,676 |
| Springs | 463 | 352 | 3,165 | 2,585 |
| Holloware | 6,008 | 7,362 | 45,558 | 51,844 |
| Doors and windows | 1,960 | 1,364 | 11,057 | 10,130 |
| TOTAL, including other manufactures not listed above | 182,325 | 213,005 | 1,271,449 | 1,299,130 |

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*News in Brief*

(*Continued from page* 187)

crane, made almost entirely of drawn steel tubing. One large order has already been executed for the Royal Canadian Air Force. Another Canadian order is being competed for, and the Ministry of Supply is interested.

JOHN FOWLER & COMPANY, LIMITED, engineers, Hunslet, are to produce most of the castings for the recently-placed £85,000 order from the Burmese Government for tractors and bulldozers, at their foundry at Sprotborough, near Doncaster. The machines have to be delivered before the end of the year and when the order is completed the company's chief field engineer will go to Burma to supervise the handing over of the machines and instruct the Burmese operators.

A SYSTEM of radio communication already working between some of the shunting locomotives at the Templeborough, Rotherham, works of Steel, Peech & Tozer, Limited, is to be extended to cover cranes and certain of the shops. Five of the works' shunting locomotives are tuned in on V.H.F. to a control tower in the centre of the works. The tower itself is also equipped with internal and national telephones. The locomotive driver's set is switched to receive, and he can switch over to acknowledge the signal. Also on order are six channel radio-frequency crane communication systems between the floor of the melting shop and the cranes.

MR. H. P. R. SCOTT was re-elected a director of F. H. Lloyd & Company, Limited, at the annual general meeting held at the James Bridge Steel Works, Wednesbury. Mr. F. N. Lloyd, chairman and managing director, presided, and reported a year of satisfactory progress. He drew attention to the fact that there is a danger that the company, along with other firms in the steelfoundry industry, may begin to suffer some of the evils of centralized control as a result of the general responsibility for the supervision of the industry with which the Iron and Steel Board is charged. He believed that, with goodwill, such dangers might be avoided.

THE CHARTERHOUSE RHEUMATISM CLINIC, of 56-60, Weymouth Street, London, W.1, in a circular letter, state that many industries recognize the heavy toll on their manpower caused by rheumatism, and give their workers every encouragement to have consultations and early treatment outside the Health Service by means of aid from the factory or other provident funds. The Charterhouse Rheumatism Clinic in London, which has branches at Ilford, Essex, and Croydon, Surrey, is a charitable organization devoted entirely to research and treatment of rheumatism, and a number of provident associations and benevolent fund institutions arrange for consultations and treatment at this clinic for their members and wives free of charge, or at reduced rates.

FINES totalling £255 were imposed on four firms in the ironfounding industry at West Bromwich recently. Pleading guilty to buying cast-iron scrap at excessive prices, they all said that had they not paid haulage and labour charges demanded by two suppliers when it was impossible to obtain scrap locally, production would have been stopped. Mr. T. E. Dale, prosecuting, for the Ministry of Supply, said all the firms were of good repute and had given the Ministry's investigating officer every assistance. The excess payments were in respect of haulage and labour, which according to the Order controlling the price of scrap were illegal. The charges should have included free delivery to the customer's premises.

## *Personal*

MR. C. J. LAKE, joint managing director of Lake & Elliot Limited, has joined the board of Bowmaker (Plant) Limited.

MR. ANDREW R. MCCOSH has been appointed a director of William Baird & Company, Limited. He is on the Board of Bairds and Scottish Steel.

LORD ROCHDALE has been nominated president of the National Union of Manufacturers. He will succeed Sir Patrick Hannon, whose term of office ends in October.

MR. A. D. MACKAY, managing director of the Bergius Company, Glasgow, has been appointed deputy chairman of Henry Meadows, Limited, Wolverhampton.

MR. S. F. WISE has resigned his appointment as purchase manager and material controller of Baker Perkins, Limited, engineers, iron and steel founders, etc., of Peterborough.

MR. H. E. JACKSON and MR. K. F. LANDEGGER have been appointed directors of Millspaugh, Limited. Mr. C. W. Aylen has resigned his directorship but has been appointed an alternate director.

MR. J. P. TAYLOR has retired from the editorship of "Shipbuilding and Shipping Record," which he has held since the foundation of the journal 40 years ago. He is succeeded by MR. DAVID AICKEN.

MR. D. R. WATTLEWORTH, director and works manager of the Workington Iron & Steel Company (branch of the United Steel Companies, Limited), has been elected chairman of the West Cumberland Productivity Committee.

THE MINISTER OF SUPPLY has appointed Mr. W. J. Richards, C.B.E., to be the director of the Radar Research Establishment. Mr. Richards is at present the chief superintendent of the Telecommunications Research Establishment, Malvern.

MR. A. D. MACKAY, managing director of Bergius Company, Limited, Glasgow, has been appointed deputy chairman to the Board. He will be responsible for implementing the policy of the main board of Henry Meadows, Limited, and will be resident at Wolverhampton.

MR. JOHN DOIG, foreman moulder, has retired after more than 50 years' service with Henry Balfour & Company, Limited, Durie Foundry, Leven. The firm and staff presented him with a watch, and the employees in the moulding shop gave him a barometer.

MR. C. L. GUEST, chief industrial engineer of Dunlop at St. James's House, has retired after 36 yrs.' service. He joined the company at Para Mills, Aston, Birmingham, in 1917, as technical assistant in the efficiency department, of which he was made manager three years later.

MR. A. G. B. OWEN, managing director of Rubery Owen, Limited, has been elected an alderman of Sutton Coldfield Town Council. Alderman Owen thus becomes not only the town's youngest Mayor, which office he held the year before last, but also the town's youngest alderman.

MR. ARTHUR A. CRAIK and MR. GEORGE FLEMING retired from the service of the Caledon Shipbuilding & Engineering Company, Limited, Dundee, recently. Mr. Craik began his association with the company in 1905, and became secretary in 1938. Mr. Fleming joined the company as iron and steel clerk in 1919, and became buyer for the shipyard the following year. They are succeeded by MR. HAROLD J. HAVARD, cashier, and MR. DAVID M. MCLELLAN, assistant buyer, respectively.

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# Raw Material Markets

## Iron and Steel

Production of castings is at a standstill in many areas, and will remain so until August 10, when work is resumed after the annual holiday. While workers enjoy this period of rest and relaxation, the foundries are not entirely silenced, as there is much activity in the carrying out of repairs to plant, relining of cupolas, and reconstruction work where necessary. Deliveries of raw material to works on holiday are in the main entirely suspended, as most establishments have sufficient on hand for the resumption of operations, and little difficulty will be experienced in augmenting supplies as necessity arises.

The main concern of managements, particularly in the case of the light and some of the jobbing foundries, is to secure sufficient orders for the restart, as at many of these establishments trade continues to be scanty, with short-time working the invariable rule. The engineering and speciality foundries are more favourably placed, as improved demands for castings are forthcoming from the motor and kindred trades, the machine-tool makers, steelworks, and collieries.

Pig-iron outputs are at a higher level than last year. Of the total tonnage now being produced about 73 per cent. consists of basic steelmaking iron, the balance being composed of about 12 per cent. of hematite and 15 per cent. of foundry and forge iron and ferro-alloys. Of the production of hematite a large proportion is sent to the steelworks, and there is as yet no sign of a slackening of their demands; in fact, present deliveries are insufficient to avoid the necessity of importing additional tonnages. The low- and medium-phosphorus irons are about sufficient for current needs, and there has been some improvement in the tonnage of hematite available for the foundries, from some areas. High-phosphorus pig-iron is in less demand.

The supply of scrap, foundry coke, ganister, and limestone is adequate for the needs of the foundries.

The steel re-rollers are in a better position in regard to raw materials than they have been for a considerable period, due to the higher level of supplies from home makers as well as imports from the Continent. They have overtaken their backlog of orders in bars and sections in the basis sizes, but are still behind in the execution of orders for small sizes, due to the lack of small billets. Steel plates are still wanted in larger quantities, but the mills are reducing the orders on their books for other finished products.

## Non-ferrous Metals

Values had tailed off somewhat at the end of last week, when trading ended at Friday midday, there being no afternoon market in accordance with the usual custom on the Metal Exchange preceding a Bank holiday. Zinc made the best showing, for there was no change on balance apart from a drop of 5s. in the October position, which closed level with July at £73 10s.

Lead certainly lost ground and closed well below the best level seen during the week, which was £97 sellers of July on July 29. On Friday last the two positions stood at £94 10s. for the current month and £90 10s. for forward, net losses amounting to 15s. and £1 15s. Tin also lost ground and at the end of the week was £10 down for cash at £572 10s. and £11 10s. lower for three months at £571.

As this report appears the copper market is reopened and the puzzle of the opening price has been resolved. As we write there is news that an important Customs smelter in the States has reduced to 29 cents, and it must be presumed that this price, or a lower figure, will become general. The opening quotation in London was expected to be around £235, but was actually £215. If events turn out in copper as they have in lead and zinc, it may be predicted that New York will follow London so far as price is concerned, and since there is no import duty on copper as there is in the case of lead and zinc, the parity of the U.S. market is likely to be fairly close to that obtaining in Whittington Avenue.

Last week the Ministry of Materials made its long-awaited announcement about disposal of stocks, from which it appears that the intention is to sell only sufficient copper to fill the distribution system, and this quantity is estimated at about 60,000 tons. This will be withdrawn from a total stock estimated at 240,000 tons, but since on some of its purchasing contracts the Government's commitments did not end till August 4, copper on their account will continue to arrive in the country for some time yet.

Just how these arrivals will be dealt with is not clear, but presumably the likelihood is that the metal will go into the country's stockpile, which will be considerable. In view of the complexity of the problem involved in the changeover from bulk purchasing to private enterprise, it would appear that matters have been handled well, and all concerned deserve the highest praise for their efforts.

Official tin quotations were as follow:—

*Cash*—July 30, £570 to £572; July 31, £570 to £572 10s.; August 4, £570 to £572 10s.; August 5, £580 to £585.

*Three Months*—July 30, £570 to £572 10s.; July 31, £570 to £571; August 4, £567 10s. to £570; August 5, £577 10s. to £580.

The following official zinc prices were recorded:—

*July*—July 30, £73 17s. 6d. to £74. *August*—July 31, £73 5s. to £73 10s.; August 4, £72 15s. to £73; August 5, £73 2s. 6d. to £73 5s.

*October*—July 30, £74 to £74 5s. *November*—July 31, £73 7s. 6d. to £73 10s.; August 4, £72 17s. 6d. to £73; August 5, £73 5s. to £73 10s.

Official prices of refined pig-lead:—

*July*—July 30, £96 to £96 10s. *August*—July 31, £93 10s. to £94 10s.; August 4, £91 10s. to £92 10s.; August 5, £93 15s. to £94 10s.

*October*—July 30, £92 to £92 5s. *November*—July 31, £90 5s. to £90 10s.; August 4, £88 to £88 10s.; August 5, £89 10s. to £89 15s.

Standard copper prices:—

*Cash*—August 5, £215 to £217 10s.

*Three Months*—August 5, £200 to £202 10s.

## Export of Copper Semi-Manufactures

The Board of Trade announces that, in view of the improvement in supplies of copper, it is no longer necessary to restrict the export of semi-manufactures of copper and copper alloys on supply grounds. Under changes in export licensing control made on August 5, semi-manufactures of copper and copper alloys may now be exported to the Commonwealth (excluding Hong Kong), U.S., and Irish Republic without licence. For exports to other destinations export licences remain necessary, but will be granted freely subject to strategic considerations.

## Wolfram Prices Lower

As from August 1, the domestic selling price to U.K. consumers of wolfram has been reduced by 7s. 6d. per unit to 327s. 6d., and scheelite ore by 12s. 6d. to 312s. 6d., according to an announcement made by the Ministry of Materials.